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HISTORICAL SKETCH OF J. HOMER LANE.

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FOR POPULAR ASTRONOMY.

The scientific career of J. Homer Lane has become a subject of permanent interest, because of the increasing importance of some of the methods used in his celebrated paper on the Physical Constitution of the Sun, which have at length become classic. And since Lane's life is very little known to contemporary readers, and only one biography of his exists, namely, that prepared by Professor Cleveland Abbe for the Biographical Memoirs of the National Academy of Sciences, vol. III, p. 253-264, it has appeared that some additional data recently gathered by the writer might be of public interest, especially in view of the extension recently made of the mathematical theory of the Sun*. The data upon which the present sketch is founded includes the following material:

(*a*) A pencil sketch of Lane, made from life by his friend, Dr. E. W. Schaeffer, of Washington, dated May 16, 1868, which was the time Lane was most occupied with the theory of the Sun. This is the only portrait of Lane in existence. It was found by Dr. Marcus Benjamin in the course of a general search for portraits of members of the National Academy of Sciences, made for the Smithsonian Institution in 1895. A photograph of Schaeffer's sketch was deposited with the Smithsonian, and a print of it also sent to Professor George Davidson of San Francisco, one of Lane's life long friends. The plate herewith produced was made from the photograph in the possession of Professor Davidson, and is therefore authentic and recognized as a good likeness, though the original pencil sketch is somewhat rough and not highly finished.

(*b*) Letters from Professors George Davidson, Asaph Hall, G. W. Hill, O. H. Tittman, Marcus Benjamin and G. W. Littlehales. Application was also made to Professors Newcomb, Abbe and others, but no additional information was elicited.

* "Researches on the Physical Constitution of the Heavenly Bodies," A. N. 4053, and another paper by the writer entitled "Researches on the Rigidity of the Heavenly Bodies," soon to appear in the same Journal.

(*c*) Information contained in the Biography of Lane prepared by Professor Abbe for the National Academy of Sciences, which was read at the annual meeting of April, 1892, and printed in the Biographical Memoirs. of the Academy, vol. III, p. 253-264.

This last paper was prepared with much care, and is therefore quite complete, and highly satisfactory. Unfortunately it seems to be known to but very few readers. If the present article serves no other purpose than to make known the new material, some of which is of decided interest, and to call attention to the details given in Professor Abbe's memoir it will not be without value to contemporary readers.

This is an age of such multiplicity of publication, and vast output of statistical material in scientific work, that many general readers and not a few scientific investigators are likely to become bewildered by the accumulations of observations, and thus be led to think that in the midst of this enormous mass of material the individual counts for nothing. A greater mistake than this could not be made.

A single principle or law universally applicable to all the data of the heavens, is vastly more valuable to the human mind than all the accumulations of disordered facts which could be put into the records of a continent. In fact the progress of science shows that the penetrating individual is every thing, and that the army of undiscerning workers is useful only in providing material for the interpretation of those gifted with a higher order of genius. In the preface to the third volume of the *Mécanique Céleste* Laplace justly remarks:

"Such is the weakness of the human mind, that it often requires the aid of a theory, to connect together a series of observations. If we restrict the theory to this use, and take care not to attribute to it a reality which it does not possess, and afterwards frequently rectify it, by new observations, we may finally discover the true cause, or, at least, the law of the phenomena."

No better description than this has ever been given of the real nature of physical science. The weakness or need of the human mind mentioned by Laplace is essentially inherent, and will always exist. Therefore consistent theory is the first prerequisite of any natural science, and there can be no real science without an appropriate theory; for theory alone enables us to understand the series of isolated phenomena which individually are without meaning or significance.

The weakness of much of our so-called Science of today arises from the fact that it has no theory. Nevertheless some persons

appear to think that facts alone may furnish the basis of intellectual contemplation and interpretation. One had as well attempt to make a rope of sand, or imagine a Universe without governing laws.

Many of Lane's efforts display evidence of a high order of talent in physical research, and a study of his life is therefore of interest to all thoughtful readers.

Viewed chronologically the principal events in his career were as follows:

1. Born August 9, 1819 at Genesee, Livingston County, New York, eldest son of Mark and grandson of Joshua Lane, of the town of Strahan, in northern New Hampshire; his mother was Henrietta (Tenny) Lane, youngest child of Lieutenant John Tenny, a soldier in the revolution, and Patience (Young) Tenny, of Bradford, Mass.

2. Being the son of a poor farmer he grew up with scant educational advantages, attending school regularly till but eight years old, and afterwards enjoying chiefly the instruction of his father and mother, except three winters, the rest of his time being occupied with work. He afterwards taught district school for nearly a year, and about this period acquired considerable local fame by the remarkable clocks he contrived for his native town. These ingenious inventions show the mechanical turn of his mind from the period of earliest youth.

3. Having found the means of subsistence by teaching, he attended Philip's Academy at Exter, New Hampshire, in 1839, when twenty years of age, and after adequate preparation entered Yale College at the beginning of the Sophomore Year. He made his way at Yale very largely by private tutoring. Many students less qualified in mathematics and the natural sciences than himself afterwards acknowledged their obligations to his clear instruction during their college courses at Yale.

4. On leaving College he taught a year in the Seminary at Castleboro, Vermont, and in 1847 was called to a minor position in the U. S. Coast Survey at Washington. On July 1, 1848, he was appointed assistant examiner in the Patent Office, on the recommendation of Professor Joseph Henry. He was promoted to be principal examiner May 1, 1851, and continued to render honorable and distinguished service in that position till September 20, 1857, when he was removed from office on political grounds. As examiner Mr. Lane was exceedingly conscientious, careful and accurate, and his work was quite above criticism. The friendship and confidence of Joseph Henry, which he always enjoyed, was

never interrupted till Henry's death. In fact for many years Henry was accustomed to refer numerous memoirs and problems to Lane, and received from him important assistance on various questions connected with his distinguished administration of the Smithsonian Institution. Those who know the unselfish character of Henry's labors, and the warm friendship he always had for Lane, will be able to understand the great pleasure and advantages of their long scientific intercourse.

5. After his removal from office in 1857, on political grounds, Mr. Lane opened an office in Washington as expert consellor in patent cases, and continued this profession of what would now be called patent lawyer for several years; without, however, abating his interest in pure science. He devoted much of his spare time to electrical contrivances of his own devising, such as electrically controlled driving clocks, visual telegraph, etc. He also studied at the request of Professor Henry the special problems arising in the operation of the Atlantic telegraph cable, but no full report of his work was ever published. But in 1860 or 1861, at the outbreak of the Civil War, business in Washington was dull, and perceiving an opportunity for increasing the means he needed for scientific research, he entered upon business in the oil district of Verango County, Pennsylvania, and continued this line of activity till 1866, when he realized a handsome sum from the sale of oil lands. While in Pennsylvania, about 1865, he resumed the problem always before his mind since his college days at Yale, of obtaining artifically a very low temperature, and constructed a machine for condensing and rarifying air in large quantities, hoping in this way to obtain a closer approximation to the absolute zero than experimenters had yet achieved.

6. When Lane returned to Washington in 1866, his new plans greatly interested his old friend Professor Joseph Henry, who had some apparatus constructed for his use from the available funds of the Smithsonian. He experimented on an extensive scale with a new form of turbine, and attained considerable success, but delayed the publication of his results in the hope of greater perfection; and meanwhile the failure of his banking firm sadly diminished his available resources, and eventually put a stop to his experiments. Professor Abbe remarks:

"In addition to the various activities thus imperfectly noticed he occupied himself with an extension or modification of his visual telegraph or semophore, the object of which was to obtain a visual method by which time can be compared between stations from fifty to a hundred miles apart to one thousandth of a second,

and the comparison carried on over a line of such stations. Apparently this method is appropriate for ascertaining differences of longitude in geodetic surveys."

From 1866 to 1869 Lane was constantly much occupied with the experimental study of the mechanical production of low temperatures, which gave him a profound knowledge of gases both in their theoretical and practical aspects. It was during the year 1868 that he conceived and carried out most of the work on his celebrated paper on the "Theoretical Temperature of the Sun", read before the National Academy of Sciences, at the Washington meeting, April 15, 1869, and published in the American Journal of Science for July, 1870.

7. On November 10, 1869, Mr. Lane accepted a posititon under the Superintendent of the U. S. Coast Survey as "Verifier of Standards in the Office of Weights and Measures". This position was very congenial to him, and he continued to hold it till his death, May 3, 1880. His services were recognized to be both valuable and original, and the Survey published in the Annual Report for 1871 Appendix 16, Lane's "Improvement in the Artificial Mercury Horizon, whereby ripples and undulations of the surface were effectually suppressed," an early account of which was presented to the meeting of the American Association for the Advancement of Science held at Troy, in 1870.

The following passage from Professor Abbe's memoir should be quoted in full:

"The high order of his mind is well shown in two important papers read before this Academy "On the Physical Constitution of the Sun," and "On the determination of the volume of a sphere." His determination of the "Coefficient of expansion of the British Standard Yard" was published after his death by the Coast and Geodetic Survey. An unpublished paper "On the Means of Measuring the Tidal Change in the direction of the Plumb Line and the Tidal Deflection of the Earth's Crust" was finished in 1874. This shows that he was an early student of problems that are now being actively discussed. It seems likely that even at this late date this and other memoirs of Mr. Lane may be worthy of publication."

"Mr. Lane's memoir of April 1869, on the "Physical Constitution of the Sun" was published in June, 1870, under the title "On the Theoretical Temperature of the Sun," and its importance has been fully recognized by Peirce, Newcomb, Ball, William Thomson, Young and others. In 1882 it was referred to by Newcomb and in 1887 by Thomson as demonstrating a paradox, namely, that

the more heat a body loses the hotter it will become; but it must be confessed that no such paradoxical statement appears in the text of Mr. Lane's published memoir, and it should, perhaps, rather be referred to Professor Benjamin Peirce, who in 1879 communicated to the American Academy certain propositions in cosmical physics (Proc. Am. Acad., xv, p. 201,) among which the following occurs: "Gaseous bodies in the process of radiating light and heat condense and become hottter throughout their mass." (See also Pierce, "Ideality in the Physical Sciences," Boston, 1881, pp. 160-198)."

"Mr. Lane's memoir accepts Helmholtz's theory of the meteoric origin of solar heat and the subsequent maintainence of the solar temperature and radiation by a process of slow gravitational condensation upon itself. He applies this theory to a gaseous Sun as distinguished from the solid or liquid Sun conceived of by former investigators, and deduces the distribution of temperature, density and pressure that must obtain throughout such a sphere of gravitating gas if it be in convective equilibrium. Although it may be possible to deduce from Mr. Lane's formulæ a demonstration of the extent to which the condensation due to cooling increases the mutual gravitation of the gaseous particles and produces heat that compensates for the heat lost by radiation, yet Mr. Lane does not do this, as he had in mind a different object. He deals only with a static condition and attempts to determine approximately the present temperature and density of the solar gas. It would seem as if he had effected a solution of the problems suggested by Sir William Thomson in 1862 in his essay "On the age of the Sun's Heat", wherein he says: "Mutual gravitation between the different parts of the Sun's contracting mass must do an amount of work which cannot be calculated with certainty, only because the law of the Sun's interior density is not known." And again: "There must be an approximate convective equilibrium of heat throughout the whole, if the whole is fluid". But we are not restricted to the hypothesis of convective equilibrium and Mr. Lane states definitely the difficulties in the way of accepting simultaneously both this modified Helmholtz theory and the mechanical theory of heat of Clausius. He shows that either the solar gases must be very different from those that occur on the Earth or else that our idea of the nature of heat must be modified, and concludes with the statement that 'of course this difficulty does not present itself when we suppose that heat is not motion.' "

Professor Abbe's account of the so-called paradox ascribed to

Lane is of considerable interest. He justly observes that it is not found in Lane's paper, and thinks it should perhaps be referred to Professor Benjamin Pierce, who first published it in the year 1879 among some propositions in Cosmical Physics. Abbe's criticism of what has been inappropriately called "Lane's Law" will be recognized as a just one, on two grounds: (1) Lane gives no such result; and (2) the mere statement that a condensing mass by cooling grows hotter, without defining in what way the temperature rises, is not a law; because the relation is vague and indefinite, and not entitled to be called a law according to the recognized canons of Physical Science.

Nevertheless independent inquiry by the present writer has convinced him that the so-called paradox probably was first reached by Lane about 1868, though never published by him. According to Professor Asaph Hall and others, it was discussed in the Clubs of Washington about 1870 as Lane's result, and spoken of as showing that gaseous masses by cooling become hotter; but never given any more exact form.

In his paper on the "Theoretical Temperature of the Sun" Lane says in a foot note: "I desire here to state that the formulæ which show the relation between the temperature, the pressure, the density, and the depth below the upper limit of the atmosphere, so far as they apply to the upper part of the Sun's body, were independently pointed out by Professor Peirce, in a very interesting paper which that distinguished physicist read before the Academy at the same session, and prior to the presentation of this paper. Also to recall a fact which I first learned from Professor Peirce's mention of it to the Academy, viz, that Professor Henry long ago threw out the idea of the atmospheric condition to which Professor Thomson has more recently given the term convective equilibrium, viz., such that any portion of the air, on being conveyed into any new layer above or below, would find itself reduced, by its expansion or compressions, to the temperature of the new layer."

It will be seen from this passage that Peirce and Lane were intimately associated in their work on the theory of the Sun; and at this late date it may never be known who preceded the other. Peirce's results were never published, and we have only indirect means of inferring what they were. In the first few lines of his paper Lane says Professor Peirce and others have shown that the theory of Helmholtz is adequate to account for the observed supply of solar heat. He continues: "Some years ago the question occurred to me in connection with this theory of

Helmholtz whether the entire mass of the Sun might not be a mixture of transparent gases, and whether Herschel's clouds might not arise from the percipitation of some of these gases say carbon, near the surface, with their vaporization when fallen or carried into hotter subjacent layers of atmosphere beneath; the circulation necessary for the play of this Espian theory being of course maintained by the constant disturbance of equilibrium due to the loss of heat by radiation from the precipitated clouds. Professor Espy's theory of storms I first became acquainted with more than twenty years ago from lectures delivered by himself, and, original as I suppose it to be, and well supported as it has been in the phenomena of terrestrial meteorology, I have long thought that Professor Espy's labors deserve a more general recognition than they have received abroad. It is not surprising, therefore, in a time when the constitution of the Sun was exciting so much discussion that the above suggestions should have occurred to myself before I became aware of the very similar, and in the main identical views of Professor Faye, put forth in the Comptes Rendus. I sought to determine how far such a supposed constitution of the Sun could be made to connect with the laws of th gases as known to us in terrestrial experiments at common temperatures. Some calculations based upon conjectures of the highest temperature and the least density thought supposable at the Sun's photosphere led me to the conclusion that it was extremely difficult if not impossible, to make out the connection in a credible manner. Nevertheless, I mentioned my ideas to Professor Henry, Secretary of the Smithsonian Institute, when he immediately referred me to a number of the Comptes Rendus, then recently received, containing Faye's exposition of his theory. Of course nothing is further from my purpose than to make any kind of claim to any thing in that publication. After becoming acquainted with his labors I still regarded the theory as seriously lacking, in its physical or mechanical aspect, the direct support of confirmatory observations, and even as being subject to grave difficulty in that direction. In this attitude I allowed the subject to rest until my friend Dr. Craig, in charge of the Chemical Laboratory of the Surgeon General's Office, without any knowledge of Faye's memoir, or of my own suggestions previously made to Professor Henry and another scientific friend, fell upon the same ideas of the Sun's constitution, availing himself precisely as I had done, of Epsy's theory of storms. Dr. Craig's ideas were communicated to a company of scientific gentlemen

early last spring, and soon after, Professor Newcomb, of the U. S. Naval Observatory, entered into a general survey of nebular hypothesis. These communications of Dr. Craig and Professor Newcomb led me to enter into a renewed examination of the mechanical embarrassment under which I had believed the theory to labor. Not any longer relying on my first rough estimate based on assumed high temperatures at the photosphere, the question was now inverted. Assuming the gaseous constitution, and assuming the laws expressed in Poisson's formulae, known to govern the constitution of gases at common temperatures and densities, what shall we find to be the temperatures and densities corresponding to the observed volume of the Sun supposing it were composed of some known gas such as hydrogen, or supposing it to be composed of such a mixture of gases as would be represented by common air. Pure hydrogen will, of course, give us the lowest temperature of all known substances, under the general hypothesis."

"The question was solved, and the results were communicated in graphical and numerical form in May or June last to two or three scientific friends, but their publication has been delayed by an unavoidable absence of several months from home." (Am. Jour. Sci., July 1870, pp. 57-59.)

These last lines show that the paper on "theoretical temperature of the Sun" was in the main completed in the early months of 1868, just about the time the accompanying pencil drawing was made.

We conclude therefore that the paradoxical result that a condensing mass grows hotter by losing heat probably was first reached by Lane in 1868, and became known among his scientific friends in Washington, but was first published by Pierce in 1879, about the same time that Ritter of Aix la Chapelle was engaged on his more elaborate and exact investigation of the condensation of gaseous masses.

Professor Abbe concludes his memoir as follows:

"During the last few years of Mr. Lane's life he suffered much from illness. His death May 3, 1880, called forth many eloquent and earnest expressions of regard from those who knew him. The following tribute from his pastor, Dr. Byron H. Sunderland, is worthy of preservation:

"Of the propriety, integrity, and simplicity of his life, of his modest shrinking from all self-assertion, or ostentation, we all well know. He has not what we should style a demonstrative man. He lived quietly within himself, and his life was engrossed

in scientific pursuits. The nature and construction of his mind was purely mathematical. This was evident in the exactitude of his language, in the most casual conversations and the most trivial subjects. His speech was slow, but exceedingly discriminating and perspicuous. This was the character of his mind and all his mental habitudes. I doubt if there ever was among scholars a more striking example of carefulness of expression in the use of terms to indicate the exact shade of thought he designed to convey." "He was very slow in all his processes and would never deviate in his reasoning or language from the precise mathematical cast in which all his conclusions were ultimately conceived."

"Such an intellectual nature must of necessity be connected with a moral disposition which would perceive at once the relations and fitness of moral truth to the highest needs of man; and this he did perceive and accept with the simplicity of a child. His was a mind never to be borne away by mere power of enthusiasm or any undue excitement of emotion. He viewed everything in the calm clear light of the rational understanding and only in this way could the moral and religious truth impress him, and in this way it did profoundly impress him."

"For the last two or three years he has been battling with the bodily disease to which he has now at last succumbed; and, of course, his favorite studies and pursuits have been in large measure interrupted, but his mind remained clear to the last. Only a day or two before he died he talked freely with me on the subject of the supernatural God and his own relations to a future life and the fitness of the Christian Scheme (as he termed it) to all the requirements of his nature, condition, and prospects. 'I rest upon it,' he said, 'as a moral certainty from its adaptability to give firmness and courage to face the future. It is wholly agreeable to me, and my repose is unshaken. Whether I am about to die now or that event be yet some way off I know not, but I trust the issue without hesitation or fear to Him who disposes all things in His own good pleasure."

We have quoted this long paragraph with Dr. Sunderland's estimate of Lane's mental qualities because it seemed singularly accurate, and affords an excellent view of the aged philosopher by one who knew him well. In announcing Lane's death to the Philosophical Society of Washington, Dr. Julius E. Hilgard, Superintendent of the Coast & Geodetic Survey, said:

"The quality of Mr. Lane's mind was truly remarkable, being chiefly characterized by an extraordinary precision of thought

and logic, and it was unfortunate that he lacked fluency of speech. Of the quietest, most retiring disposition, he was personally known to but few; diffident in manner, and not given to many words, yet when he did speak his rare logic was such as to carry conviction. In his writings his clearness of mind became manifest; so lucid was it and so fully were those qualities and soundness of precision appreciated that his co-laborers never thought an induction safe until it had passed through the alembic of his criticism."

"His exceedingly generous disposition led him to devote a considerable portion of his income to the assistance of two sisters and a brother; and in order that he might extend to these all the aid in his power he never married."*

Some further valuable impressions of Lane may be gotten from private letters now in the writer's hand. Dr. O. H. Tittman, Superintendent of the U. S. Coast & Geodetic Survey, says:

"My recollection of him is that he was of medium height, rather below than above, and of slender build. His head was large and his face shaven or beardless. He had large grey-blue eyes which always seemed to look far beyond the person whom he was addressing, and which always gave him an air of abstraction. His manner was gentle and his speech slow and deliberate, and he was usually dressed in a black frock coat."

Professor Asaph Hall says:

"I used to see J. Homer Lane in Washington at the scientific meetings, but never knew him intimately, and so do not feel like saying much about him. He was a man of medium height, spare but strongly built, with a big head, and large eyes; a striking looking man. I think he was very modest, and even bashful."

Professor G. W. Hill writes:

"In seeking information about J. Homer Lane from me you have come to the wrong quarter.

"I suppose I must have seen him more than a dozen times, for he used occasionally to come to the Philosophical Society in Washington, and also to the meetings of the National Academy. But it was a long time before I learned his name. He seemed to me the most unsocial man I had ever seen. He never spoke to anybody and nobody spoke to him. I never heard him read a paper at any of these meetings.

* Bulletin of the Philosophical Society of Washington, May 8, 1880, vol. iii. p. 123.

"After his death Hilgard gave an account of him to the Philosophical Society, speaking in high praise of his devotion to science. His lack of sociality was due to almost total deafness. He was a slim but not a tall man, somewhat stooping, and with a haggard countenance, as if he was in poor health."

Dr. Hill's impression of Lane corresponds to the later years of his life, when his health was infirm, but it agrees with the other reports as to his non-communicative disposition, especially after his hearing became impaired. It is justly remarked by Abbe that Lane's fastidious desire for mathematical accuracy caused him to publish but few results of the many researches on which he was from time to time engaged. But when we consider the variety of subjects which occupied his attention, and the ability and originality he always displayed in physical, mechanical, and mathematical invention, it is evident that his work must be ranked among the most important of the early American investigators. It is not too much to say that some of his researches are destined to stand forever, while others are more dependent upon the progress of invention, and therefore chiefly of temporary interest. In the long run, it is not the number, but the permanence of researches that counts. All of Lane's work was quite free from the taint of commercialism, and therefore it is not remarkable that the faithful philosopher was honored and esteemed by the foremost thinkers of his day.

Publications of J. Homer Lane.
(Quoted from Professor Abbe's Memoir.)

"1. On the law of electric conduction in metals.
Am. Jour. Sci., 1846 (2) I. 230-241.

2. Notice of a novel mode of discharging a Leyden battery, with an explanation of its theory.
Am. Jour. Sci., 1849 (2) VII, 418-419.

3. On the law of the induction of an electric current upon itself and of electrical discharges in straight wires.
Proc. Am. Assoc. Adv. Sci. Charleston, 1850, III, 359-361.

4. On the law of the induction of an electric current upon itself when developed in a straight prismatic conductor, and of discharges of machine electricity through straight wires.
Am. Jour. Sci. 1851 (2) XI, 17-35.

5. A visual method of effecting a precise automatic comparison of time between distant stations.
Am. Jour. Sci., 1860 (2) XXIX, 43-49.

6. On a mode of employing instantaneous photography as a means for the accurate determination of the path and velocity of a shooting star, with a view to the determination of its orbit.
   Am. Jour. Sci., 1860 (2) XX, 42-45,
   Jour. Photogr. Soc., 1860, VI, 302-304.
7. On the physical constitution of the Sun (title only).
   Report Nat. Acad. Sci., Washington, April 15, 1869.
8. Report to Mr. Hilgard of observations on the total solar eclipse as observed at Des Moines, Iowa, August 7, 1869 (dated August 28, 1869).
   Coast Survey Rep., 1869, 42, 167-169.
9. On observations of the eclipse of the Sun made at Des Moines, Iowa, August 7, 1869. A report dated August 28, 1869, to the Superintendent of the United States Naval Observatory.
   Published in Astr. & Met. Obs. U. S. Naval Observatory, 1867, Append II, 165-173.
10. On the theoretical temperature of the Sun, under the hypothesis of a gaseous mass maintaining its volume by its internal heat and depending on the laws of gases as known to terrestrial experiments.
    Am. Jour. Sci. 1870 (2), L. 57-74.
11. Description of a new form of mercurial horizon, in which the vibrations are speedily extinguished.
    Proc. Am. Assoc. Adv. Sci., Troy, 1870. XIX, 59-61.
12. Report to Professor Benjamin Peirce, Superintendent, on observations of the total solar eclipse observed at Catania, Sicily, on December 21, 1870.
    Coast Survey Rep., 1870, 120-125.
13. Description of a new form of mercurial horizon (invented for the use of the office of Weights and Measures, in the report of which its uses will be mentioned, but the description of the apparatus is given in the report of the Coast Survey).
    Coast Survey Report, II, 181-192.
14. On the determination of the volume of a sphere (title only).
    Proc. Nat. Acad. Sci., New York, Oct. 30, 1873.
15. On the coefficient of expansion of the British Standard Yard, bar bronze No. 11, being a new discussion of the experiment of Sheepshanks and of Clarke.
    Report C. & G. Survey, 1877, 148. 155-166.

(This is Chapter IV of the Report of J. E. Hilgard on the Com-

parison of American and British Standard Yards, dated July 10, 1880, Append XII. C. & G. Survey Report, 1877.)"

The writer takes pleasure in acknowledging his special obligations to Professor George Davidson of San Francisco, and Dr. O. H. Tittman of Washington; also to Professors Hall and Hill and Dr. Benjamin and Dr. Cyrus Adler of the Smithsonian Institution, and Mr. G. W. Littlehales, President, Philosophical Society, Washington.

U. S. Naval Observatory,
Mare Island, California,
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SCOTTISH ASTRONOMY.

HECTOR MACPHERSON JR.

FOR POPULAR ASTRONOMY.

There is a popular impression that in astronomy Scotsmen have not specially distinguished themselves. Certainly the astronomers of Scotland have been few compared with the illustrious Englishmen, Germans, Frenchmen, Italians and Americans who have studied the heavens; but when consideration is taken of the size of the country and its unfavorable climate, we find that Scotland has done remarkably well. The most remarkable feature is that so little is known, even in Scotland of men like Ferguson and Henderson. To add to the confusion many English, American and Continental writers refer to our Scottish astronomers as Englishmen, thus depriving Scotland of the honor of their production. The following sketch should indicate what Scotsmen have actually accomplished in the realm of astronomy.

The first Scottish astronomer was James Gregory (1638-1675) a native of Aberdeen and inventor of the form of the reflecting telescope known as the Gregorian. In 1666 Gregory became Professor of Mathematics at the University of St. Andrews and in 1674 in Edinburgh, where he died in the following year.

Scotsmen accomplished little scientific work until after the Union; and we can easily understand that science could not flourish in the midst of the Covenanting and Jacobite wars. Colin Maclaurin (1698-1746) a native of Kilmodan in Argyllshire, was more of a mathematician than an astronomer, but he deserves mention from the fact that he was the only original British mathematician of his age, perfecting the work of Newton and

and its application to astronomy. He died in 1746 at York, where he had fled from the forces of Prince Charles, who had occupied Edinburgh.

James Ferguson (1710-1776) was the virtual founder of Scottish Astronomy. A native of Rothiemay, in Banffshire, where his father was a farm laborer, he commenced his observations as a shepherd boy on his native hills watching the stars by night as he tended his sheep. He ingeniously measured the positions of the stars by means of a thread of beads marking these positions on paper. Ferguson was possessed of a wonderful genius for mechanics and constructed large numbers of machines representing the planetary motions. After receiving assistance from the local gentry, Ferguson removed in 1741 to London, becoming famous as the author of "Astronomy Explained upon Sir Isaac Newton's Principles"—a noble and profoundly religious work, which first started Herschel on his astronomical career. Ferguson also outlined a theory of the Creation which almost foreshadowed the nebular hypothesis of Herschel and Laplace. Ferguson received a pension from George III, and died in 1776, in his sixty-seventh year.

Alexander Wilson (1714-1786) was a native of St. Andrews. After a successful career as owner of a type-foundry first in St. Andrews and afterwards in Glasgow, he was appointed in 1760 Professor of Astronomy in the University of Glasgow. He is best known for his observations of sun-spots, which enabled him to demonstrate that the spots are cavities in the atmosphere of the Sun. Wilson was the originator of the theory of the Sun which stipulated for the existence of a cool, dark globe below the photosphere, a theory afterwards developed by Herschel, but long since abandoned. Wilson—who was a close personal friend of Herschel—resigned his chair at Glasgow in 1784 and died in Edinburgh in 1786. He was succeeded as Professor of Astronomy by his son, Patrick Wilson (1743-1811) who held the post till 1799.

Thomas Dick (1772-1857) born in Dundee a few years before the death of Ferguson, combined the qualities of astronomer and theologian. Originally a probationer of the Secession Church, Dick afterwards became a schoolmaster, and erected a private observatory first at Methven and afterwards at Broughty Ferry, near Dundee, where he carried on a series of observations. He devised the method of observing Venus in daylight, an idea lost sight of until applied by Professor Schiaparelli sixty years later. In 1823 Dick published "The Christian Philosopher," his recon-

ciliation of science and religion, a masterly work, well worth study to-day. In addition to this he published quite a number of theological and astronomical works, to the perusal of which Professor Barnard attributes his early interest in astronomy. Dick died in 1857, in his eighty-fifth year.

Thomas Henderson (1798-1844) also a native of Dundee, was the first Astronomer-Royal of Scotland. The son of a tradesman, he went to Edinburgh to seek his fortunes as an advocate's clerk, pursuing the study of astronomy in his leisure. At length he became so famous that in 1832 he was appointed Astronomer-Royal at the Cape of Good Hope. Here he made the first determination of the distance of the stars, measuring the parallax of Alpha Centauri and thus—independently of Bessel—solving the great problem. In 1833 Henderson returned to Scotland on account of ill-health and in 1834 was appointed Astronomer-Royal of Scotland and Professor of Astronomy in the University of Edinburgh. This post he held for ten years, making a large number of observations. He died in 1844, at the comparatively early age of forty-six.

John Pringle Nichol (1804-1859) was a native of Brechin in Forfarshire, where his father was a farmer. After studying theology at Kings College, Aberdeen, he was appointed Rector of Montrose Academy, pursuing the study of astronomy while in this position. In 1836 he was appointed Professor of Astronomy in the University of Glasgow, and Director of the Glasgow Observatory. He rendered many important services to astronomy, perhaps chiefly in the literary department of the science. As a writer Nichol is unsurpassed, and from his magnificent conceptions of the Universe, his feeling of awe for the wonders of the heavens, he may be called the Flammarion of Scotland. His works, such as "The Architecture of the Heavens," "Phenomena and Order of the Solar System" are crowded with beautiful and sublime passages. Another of his services was his defence of the nebular theory in its time of unpopularity. He died at Rothesay in 1859, at the age of fifty-five.

John Lamont (1805-1879) born at Braemar in Aberdeenshire, was sent in 1817 to a school at Ratisbon, in Bavaria. In 1828, after some years' interest in astronomy, he became assistant astronomer in the Munich Observatory. He was appointed in 1835 director of the Observatory, and in 1852 Professor of Astronomy in the University of Munich. In 1840 Lamont commenced a series of magnetic observations and in 1851 discovered the ten years' magnetic period, which was shown to coincide

with the sun-spot period. In practical astronomy Lamont was a master and it was well remarked that his name "must be permanently connected with the history of astronomy of our time by the excellent series of zone observations carried out under his direction at the Munich Observatory." He published ten star-catalogues, containing reference to 34,674 stars the last of which appeared in 1874; while his name is famous for work on comets, planets, and satellites. Honored all over Germany and knighted by various governments, Lamont died in Munich in 1879 in his seventy-fourth year.

Nichol's successor as director of the Glasgow Observatory was Robert Grant (1814-1892) a native of Grantown-on-Spey, and the son of a tradesman. Grant was educated at Kings College, Aberdeen, after which he moved to London as a book-keeper, and in 1847 to Paris, where he attended the astronomical lectures of Arago and Le Verrier. Returning to London in 1847 he published in 1852 his "History of Physical Astronomy" for which he received in 1856 the Gold Medal of the Royal Astronomical Society. Grant's history was for long a standard work and indeed is still of great value. In 1859 Grant returned to Scotland as director of the Glasgow Observatory and Professor of Astronomy in the University of Glasgow in succession to Nichol. In this position he pursued the study of both practical astronomy and meteoric astronomy. In 1883 he published a catalogue of 6415 stars from his observations at Glasgow. A second catalogue of 2156 stars—in the introduction to which he gave 192 new determinations of proper motion—was published shortly before his death, which took place at his birthplace, Grantown-on-Spey, in 1892 in his seventy-ninth year.

William Harkness (1837-1903) is better known as an American than a Scottish astronomer, although he was a native of Ecclefechan, Dumfriesshire. As a boy he emigrated to the United States with his parents, and subsequently he was employed at the Naval Observatory, Washington, from which he retired in 1899. He died at Jersey City, New Jersey in 1903. Besides his regular observations his most important work is a careful discussion of the solar parallax and its related constants.

Among living Scottish astronomers, the most notable names are those of Sir David Gill, Astronomer-Royal at the Cape of Good Hope, and Mr William Peck, Astronomer to the City of Edinburgh. Born in Aberdeen in 1843, Sir David Gill, after education at Marischal College, Aberdeen, was early attracted to astronomy. After working in a small private observatory he

was appointed in 1873 director of the private observatory erected at Dunecht, by Lord Lindsay, now Earle of Crawford and Balcarres. In 1879 he became Astronomer-Royal at the Cape, and since his appointment has greatly increased our knowledge of the southern heavens. He has maintained the traditions of Henderson and of the Cape Observatory by his measures of stellar parallax. Sir David Gill has measured the distances of all the notable southern stars, such as Sirius Achernar, Alpha and Beta Centauri and others, as well as smaller stars; while to his skill we owe several reliable determinations of the distance of the Sun. Another of Sir David's important works is the *Cape Photographic Durchmusterung*, commenced in 1885 and finished in 1900, representing half a million stars. To his initiative, too, is due the International Chart of the Heavens, now far advanced towards completion. His services to astronomy have been fully recognized. He was knighted in 1900 and has received many honorary degrees. He is universally recognized as the senior astronomer of Scotland, and one of the foremost astronomers in the world.

Mr. William Peck, Astronomer to the City of Edinburgh is a native of Castle Douglas, Kirkcudbrightshire, where he was born in 1862. At a very early age he became devoted to astronomy and commenced in 1883 his astronomical lectures, which have made his name famous in the Scottish capital. After working for sometime in a private observatory at Murrayfield, Midlothian, he was in 1889 appointed Astronomer to the City of Edinburgh. When the new Royal Observatory of Scotland was erected on Blackford Hill, the Town Council of Edinburgh acquired the institution on the Calton Hill and converted it into a City Observatory, Mr. Peck being appointed director. The Observatory is well endowed with instruments, possessing a 22-inch refractor, —the largest in Scotland. It is opened to the public for educational purposes and is greatly taken advantage of by the citizens. Besides observations of the Moon and planets, Mr. Peck has given much attention to practical astronomy, and since 1890 has been engaged on a gigantic catalogue—now in press—which contains every star down to a given magnitude, the magnitudes being compiled from every known authority and the combination of these reduced to a standard scale. In connection with this Mr. Peck has constructed a complete series of charts, engraved on copper plates by the aid of a machine invented and constructed by the City Astronomer. Mr. Peck is the author of several works "The Constellations and how to find them," "A Handbook

and Atlas of Astronomy" (1890) and "The Observer's Atlas of the Heavens" which appeared in 1898, a magnificent work giving a series of charts constructed with the utmost skill and care. During the recent total eclipse of the Sun, Mr. Peck was the chief Scottish astronomer who visited Spain, taking up his position at Burgos. He succeeded in securing a fine series of photographs by the aid of an instrument which he had specially constructed for the purpose. Mr. Peck's services to astronomy have gained for him a high position in the science and he is well known, not only as an observer and thinker, but as an eloquent lecturer on his favorite science. Like most of the Scottish astronomers, also, Mr. Peck is a self-made man.

Perhaps the most noticeable feature about our Scottish astronomers is the combination in them of two qualities rarely associated, namely, practical observation and great speculative power. If the native astronomers of Scotland have been few, those whom we can claim as Scottish have been men of first-rate ability, whose names will be for ever remembered in the history of the science which they enriched with their researches.

Johnsburn,
Midlothian, Scotland.

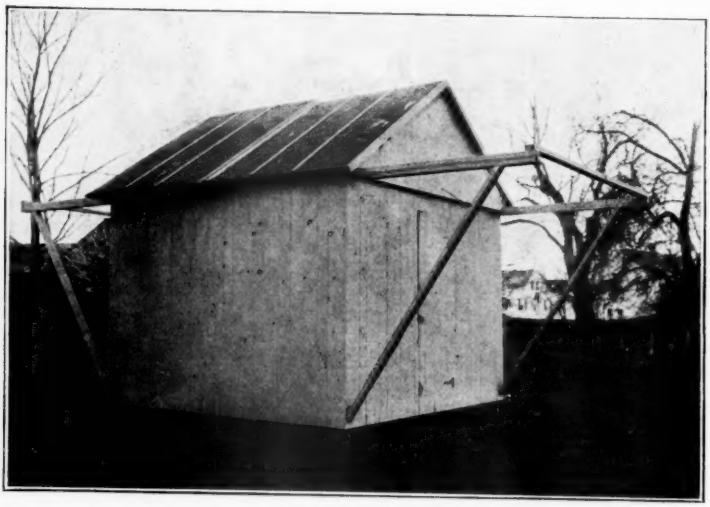
AN AMATEUR'S OBSERVATORY.

JOEL H. METCALF.

For Popular Astronomy.

The writer's first instrument consisted of a two-inch spy-glass, by a French maker, which glass he mounted equatorially. He obtained a high power (100) negative eye-piece from Alvan Clark and Sons, which showed enough planetary detail to keep up his interest. A few years after this he was fortunate enough to get a three and five-eighths inch glass by Henry Fitz; this he also mounted equatorially and enjoyed for many years. With this instrument he has often watched transits of the shadows of Jupiter's satellites. The cost of this glass took all his savings for a year, but the money was never considered wasted. A few years ago that instrument was sold for a large percentage of its cost.

In 1901 he was fortunate enough to come into possession of a seven-inch equatorial manufactured by Alvan Clark and Sons in 1885. It had been the property of Elisha Arnold, a wealthy amateur astronomer of Keesville, N. Y., and after his death his exec-



OBSERVATORY.

OBSERVATORY OPEN.

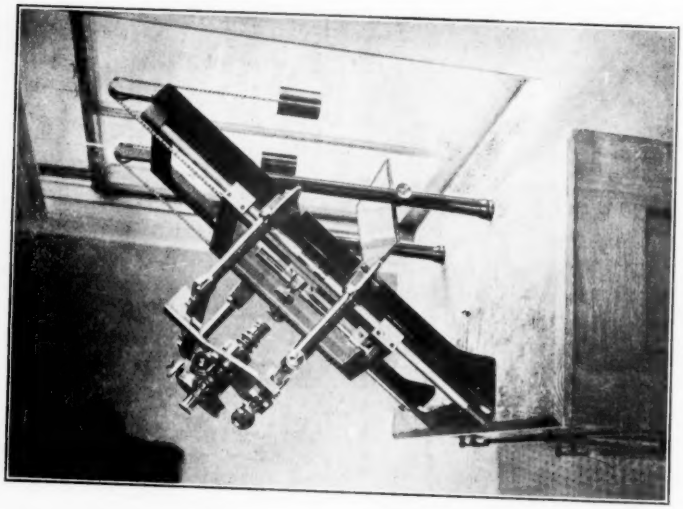
utors sold it at a nominal sum. The telescope had been little used and was practically as good as new with all the excellence which one expects from the Clark glasses. In addition to the equatorial, which was the best for the size the Clarks could make, the outfit contained a small transit instrument, a four-inch telescope with altazimuth mounting, a fine micrometer, and a spectroscope which could be used either with a single prism or a grating, both of which were provided.

In the Observatory at Keesville, the instrument was mounted in a very substantial dome, being fastened to a fine cut granite base weighing about a ton. In a February when Lake Champlain had frozen over, the whole outfit was loaded on sleds and started across the Lake on the ice. The ice was thick enough—but there are always long cracks in the Lake due to expansion and contraction! These cracks will sometimes run out as far as four miles from islands. The moving went well until off Juniper Island, when the large sled having the dome and the cut granite pier fell into a crack, and would have gone to the bottom but for the projecting sides of the dome which reached out to the solid ice! There the load stuck with the water within a foot of the top of the dome until after three days when, by laying timbers on the ice, and rigging derricks, the whole was rescued with the exception of the mounting of the four-inch telescope, which now lies buried peacefully in the bottom of the Lake!

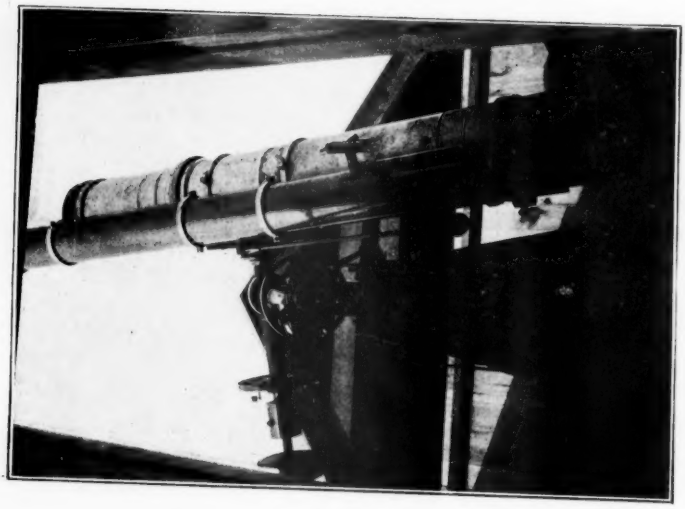
The Observatory was installed in Burlington, Vermont, until 1905 when the writer moved to Taunton, Mass., and then presented the house and dome to the University of Vermont, his previous experience in moving it not being an encouragement to repeat the experiment.

In Taunton a very simple but successful house has been constructed. As can be seen from the photograph the building is an unpretentious one of the sliding-roof pattern, which cost, including the substantial concrete base, only one hundred dollars. It is twelve feet square. The roof is made in two parts, one-half a little larger than the other, so one slides over the other about six inches when it is closed, and gooves run up and down at the joint of the lower section to prevent water from working into the house. The joint is so satisfactory that no water or snow enters—which could not have been said of the slit in the old dome.

The sections of the roof are each mounted on four wheels which run on an iron track fastened to the long beams which are twice the length of the house. There is not the least difficulty in opening and closing the roof. This is accomplished by pulling



MEASURING MACHINE.



TELESCOPE AS SEEN THROUGH THE DOOR.

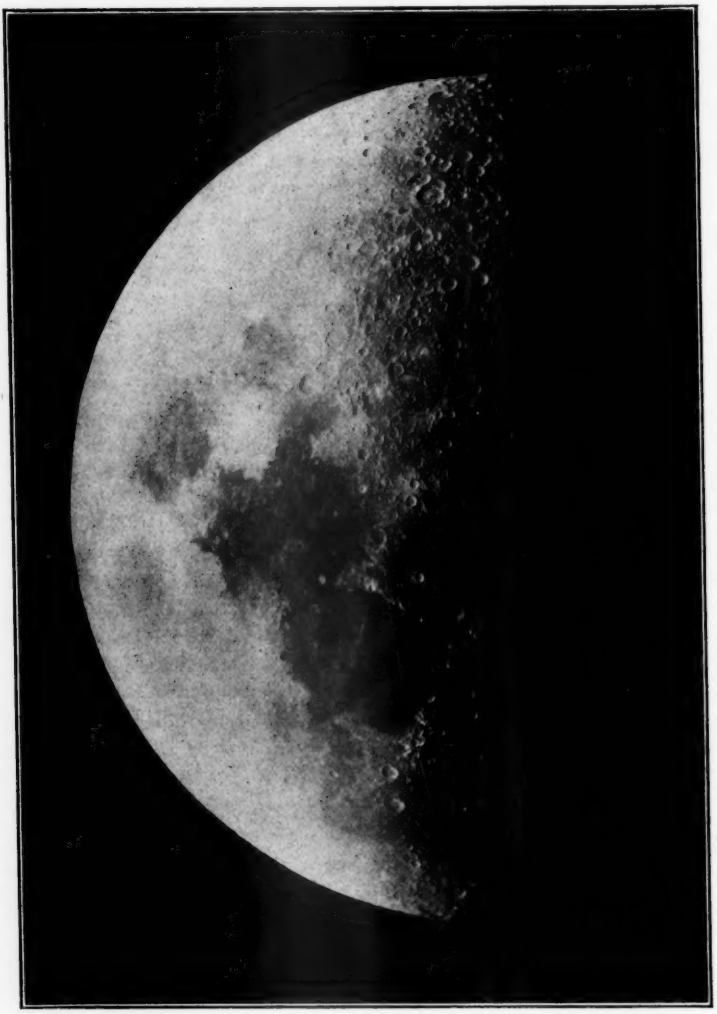
two ropes fastened in the middle of the roof and in the middle of the cross-pieces of the projections.

The limitation of such a simple covering for a telescope is the fact that the roof, even when rolled off to its greatest extent shuts off some of the horizon, both north and south. In the present case, however, this is no less because buildings and trees interfere with the view in those directions any way.

For many years now, dating in fact from the writer's first interest in astronomy, he has spent considerable time grinding lenses. The mysteries of the art had to be learned by long and bitter experience. He has not been entirely without help however, for he found Mr. Carl Lundin of the Alvan Clark and Sons Corporation and Mr. J. A. Brashear more than kind in answering questions when difficulties arose. In this way the observatory has been provided with an eight-inch comet-seeker of about 80 inches focus, mounted in the broken-backed form with a four-inch total reflection prism to reflect the light at right angles. In this way the whole heavens can be swept, looking always in a horizontal direction and being obliged to travel around the mounting only once to cover the whole sky. As the horizon is so much shut in by trees at Taunton, this instrument is only used during summer vacations on Lake Champlain.

The most pretentious undertaking of the writer is a twelve-inch portrait lens of the Petzval Voigtlander type which was completed last autumn and put in working order in November. The glass consists of tested discs imported from Parra Mantois & Co., Paris. The front combination had its curves computed by Professor F. R. Moulton, and may be used separately with a focal length of ten feet, six inches. With the back combination in place the focal length is eighty-four inches and thus works at a spread of seven feet. It covers an 8x10 inch plate well with star images over about four degrees. This twelve-inch lens has been mounted on the seven-inch visual tube. At first sight it might seem impossible to mount a twelve-inch portrait lens beside a seven-inch and be carried satisfactorily by the mounting. It must be said, however, that the Clark mounting is very heavy and was originally designed for a larger telescope. Then again it must be noted that a larger part of the portrait lens is cast of aluminum, thus reducing the weight greatly. The result is very satisfactory for the whole is well balanced and the clock runs as well as ever, in any position of the telescope.

The last instrument of this amateur outfit is a measuring machine for astronomical photographs. It is like the Oxford and



TAKEN WITH 7-INCH CLARK VISUAL TELESCOPE,
Bausch & Lomb Ray Filter and Comet Eye-Piece.

Greenwich machines except that it holds a larger plate, and differs in some details of the lens and micrometer scale.

The micrometer was made by Troughton Simms. The lens is a Teiss Planar doublet for microscopic enlargement and is found to have no measurable distortion over the field used, and is thus a great improvement over single lenses. The micrometer scale was made by Teiss and Company and is a most satisfactory one.

As the writer could not afford to buy the measuring machine complete for an 8x10 plate he had the rest done himself in this country, thus getting a machine which he believes to be as good as any, for less than half the cost of the whole complete.

In a machine where *réseau* is impressed on the negative the essential part is to measure accurately positions between parallel lines 5mm. apart. This throws the work on the micrometer and the lens, all the rest of the apparatus being simply a means for bringing the *réseau* squares under the microscope, thus with the exception of the micrometer the machine need have only ordinary accuracy.

The writer intends to use his leisure for the present, searching for new asteroids. In December he had the good fortune to discover 1905 SF and 1905 SH, and three more in February, 1906, and his success in photographing faint known asteroids, as for instance 460 Seania, 13.7 magnitude, in fifty minutes, is very encouraging.

Of course the whole interest of this article is the encouragement it gives to amateurs. The observatory has no special excellence in any of its parts but it shows how one with little means, if he is willing to spend the time and make things himself, can provide instruments which will give him much enjoyment in the using. Should he tell the whole sum in cash actually expended on the whole outfit, the readers of POPULAR ASTRONOMY would be incredulous.

Taunton, Mass.

THE ARC-METHOD FOR DESCRIPTIVE ASTRONOMY.

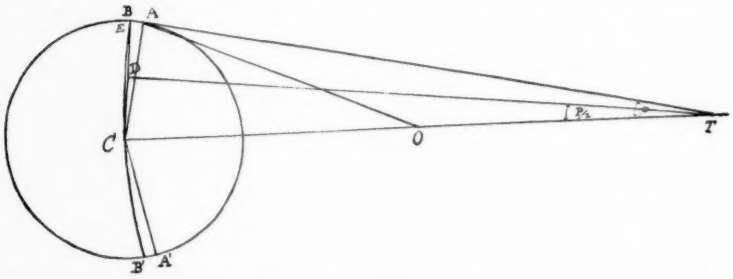
KURT LAVES.

FOR POPULAR ASTRONOMY.

The recently developed tendency of reducing the amount of mathematical preparation in our colleges and universities has brought about a change in the teaching of Descriptive Astronomy. It is now not always possible to make trigonometry a prereq-

uisite of this course and on that account certain characteristic and important features of the subject matter formerly presented must now be pushed more into the background. It is especially the problem of solving triangles by means of the trigonometrical functions with its various applications in astronomy which seems necessarily to be omitted from the course. Since all determinations of distances by means of a known base line and the observed parallactic angle fall into the this category, it seems not useless to point in what follows to a mode of solution which is valid for small values of a parallactic angle and which uses nothing but elementary conceptions. It is a well enough known proceeding and stress is laid on it for the only reason that it is not often enough called into service. The inquiry into the error committed by this method is a logical desiratum, and it is hoped that the method given proves to be useful to the teachers interested in the method.

In the right triangle ATC the angle at T is the parallactic angle which we shall designate by p. If AC and p are known we can find (1) $CT = \frac{CA}{\sin p}$. To obtain CT without using the trigonometric function, we describe an arc of a circle with radius



CT about T. B and B′ are the intersections of this arc with the previously constructed circle about C. The angle BTC = P will differ by a small quantity from p. Starting in the first approximation from the hypothesis that p = P we have $\frac{\overset{\frown}{CB}}{CT} = p$, if we further assume that the arc $\overset{\frown}{CB}$ can be replaced by the radius r = $\overline{CB}$ we see that we obtain $CT = \frac{CB}{p}$...(2). What error is committed by introducing the two assumptions namely p = P and CB = $\overline{CB}$ we shall investigate a little later, at present it is well

to keep the significance of the equation $\frac{\overset{\frown}{CB}}{CT} = p$ well before us. It is known that when we bend the radius of a circle along the circumference there will be 206265″ contained in the arc it subtends. If in particular the angle p is 1″ then will the length $\overset{\frown}{CB}$ be $\frac{1}{206265}$ CT. If on the other side $\overset{\frown}{CB}$ is measured in miles and we know the angle p equals 1″, then will CT be 206265 times the length of $\overset{\frown}{CB}$. In the astronomical problems we know the length of the straight line-base $\overline{CB}$ or CA but not the curved line $\overset{\frown}{CB}$, but on account of the small angles p involved the difference $\overset{\frown}{CB} - CB$ is a quantity which falls below the standard of observational accuracy. To make sure that we keep inside the proper limits we now proceed to investigate into the error committed by this short process.

1. $P = p + \ldots\ldots$

We have $\overset{\frown}{CB} = CT.P$ and from triangle CDT:

$$r = \overline{CB} = 2\ CT \sin \frac{P}{2} \text{ but we had before}$$

$$r = CA = CT \sin p.$$

From the last two equations we obtain $2 \sin \frac{P}{2} = \sin p$ .....(3)

or $\sin P/2 = \sin p/2 . \cos p/2$; by elementary processes we derive from this equation the following one

$$\operatorname{tg} \frac{p - P}{4} = \operatorname{tg}^2 p/4 . \operatorname{tg} \frac{p+P}{4} \quad (4)$$

We obtain a more convenient and sufficiently accurate form by putting upon the right side $P = p$, then we obtain

$$p - P = \frac{4}{\sin 1''} \operatorname{tg} p/2, \operatorname{tg}^2 p/4 \ldots\ldots (5).$$

solving this equation for a number of individual values of p we find e. g., that for $p = 1°$ the difference between p and P will amount to only 0″.137 and for $p = 26'$, $p - P$ will amount to 0″.01. The extreme case where p is about 1° corresponds to the parallax of the Moon, the largest one in the solar system. Even in this case we may for elementary purposes neglect the difference between p and P.

II. We next proceed to find out what error we shall introduce in the determination of CT when instead of employing the length of the arc $\overset{\frown}{CB}$ we bend the straight line $\overline{CB} = r$ along the circum-

ference so that $\overset{\frown}{CE} = r$. Joining the end-point E with T we call the angle ETC = P′. Our present problem is now to assign to the angle P = BTC such a value that the difference P — P′ will fall below the error of observation of P. The two equations involving P and P′ are evidentially

$$CB = 2\ CT \sin \frac{P}{2}$$

and

$$\overset{\frown}{CE} = CT.P'.$$

The first equation when solved for P gives $P = 2 \text{ arc sin}\left(\frac{\overline{CB}}{2CT}\right)$ forming the difference between P and P′ we obtain

$$P - P' = 2 \text{ arc sin } \left(\frac{\overline{BC}}{2CT}\right) - \frac{\overset{\frown}{CE}}{CT} \qquad (6).$$

The well known power series for arc sin x is:

$$\text{arc sin } x = \frac{x}{1} + \frac{1}{2}\cdot\frac{x^3}{3} + \frac{1.3}{2.4}\cdot\frac{x^5}{5} + \ldots\ldots$$

Substituting the value $x = \frac{CB}{2CT}$ into this series and using it in (6)

we get $$P - P' = \frac{\overline{CB}}{CT} + \frac{\left(\frac{\overline{CB}}{2CT}\right)^3}{3} + \frac{1.3}{4}\frac{\left(\frac{\overline{CB}}{2CT}\right)^5}{5} + \ldots\ldots - \frac{\overset{\frown}{CE}}{CT} \qquad (7)$$

Since by hypothesis $\overset{\frown}{CE} = \overline{CB}$ we obtain

$$P - P' = \tfrac{1}{3}\left(\frac{\overline{CB}}{2CT}\right)^3 + \frac{1.3}{4.5}\left(\frac{\overline{CB}}{2CT}\right)^5 + \ldots\ldots$$

Putting P — P′ = 0″.01 we solve the last equation for $\frac{\overline{CB}}{2CT}$ or $\frac{1\overline{CE}}{2CT}$ and *we find that for all values of P <2168″ or 36′ 8″ the introduction of the length of the radius CB instead of the arc $\overset{\frown}{CB}$ of which $\overline{CB}$ is the chord will produce an angular error <0″.01.*

Comparing the result with the result under I we see that the method proposed will certainly involve an error <0″.01 for all values of a parallactic angle <26′.

For all purposes of a class in Descriptive Astronomy we may greatly increase the realm of applicability remembering that the Moon's parallax affords the biggest value of a parallactic angle and that in this case p is about 60′. That we have considered the angular error rather than the linear error in CT will be

granted to be a legitimate preference since for a given base CB the error in CT corresponding to an angular error of 0″.01 can at once be ascertained.

A few examples that show the applicability of the arc-method will not be out of place.

EXAMPLE 1. Two luminous points A and B are ten feet apart. An observer views them from a station O so that OA = OB. What is the distance OA in order that the observer's eye may just distinguish them as separate points?

Solution: In order that the images A and B fall on distinct nerve-ends of our retina it is necessary that the angle AOB be >60″. For an angle of 1″ we have $\frac{AB}{OA} = \frac{1}{206265}$, for an angle of 60″ we have $\frac{AB}{OA} = \frac{60}{206265}$ Since AB = 10ft. ∴ OA = 34544 ft.

EXAMPLE 2. Find the distance from the Earth's center to the Sun if the horizontal equatorial parallax of the Sun is 8″.8.

Solution. The radius of the Earth-globe is 4000 miles and we have

$$CT \times 8''.8 = 4000 \text{ miles or } CT = 4000 \text{ miles} \times \frac{206265}{8.8}.$$

$$CT = 93{,}800{,}000 \text{ miles.}$$

EXAMPLE 3. The apparent diameter of Venus when nearest to the Earth is 67″, it is then at a distance of 26,000,000, miles. Find its diameter in miles.

Solution: $CT \times 33''.5 = CB$ or 26 Mill. $\frac{33.5}{206265} = CB$, $CB = \frac{26 \text{ Mill. miles}}{6763} = 3859$ miles.

The University of Chicago,
February 9, 1906.

JUPITER'S FAMILY OF COMETS.

W. W. PAYNE.

Recently a letter came from a prominent astronomer in England, requesting that we make a revision of the cut illustrating Jupiter's Family of Comets that was printed in the publication in October, 1893, saying that he had found the cut useful, and that he hoped to have the advantage of it, in his work on comets, if brought down to date.

At his earliest opportunity, Dr. H. C. Wilson of this Observatory,

ELEMENTS OF THE JUPITER FAMILY OF PERIODIC COMETS.

Comets of which more than one Apparition has been Observed.

Name.	Period in yrs.	Time of Perihelion Passage. Greenwich M. T.	Perihel'n Distance	Aphelion Distance	e	π	Ω	i	Mean Equinox	Calculator and Reference.
						° ′ ″	° ′ ″	° ′ ″		
Encke	3.299	1905 Jan. 11.806	0.33865	4.09317	0.847172	159 02 39	334 27 08	12 35 37	1904.0	Kaminsky and Ocoulitisch, A.N. 166,27, 207.
Tempel 2	5.279	1904 Nov. 10.435	1.38787	4.67549	0.542211	306 44 30	120 59 52	12 38 55	1904.0	Schulhof, A. N. 166,25.
Brorsen	5.456	1890 Feb. 23.882	0.58767	5.61021	0.810393	116 23 18	101 27 36	29 24 08	1890.0	E. Lamp, Pub. K. Sternwarte in Kiel VII.
Tempel-Swift	5.678	1903 Jan. 24.178	1.15160	5.21390	0.638173	43 48 20	290 12 00	5 26 21	1900.0	Bossert, Annuaire 1905.
Winnecke	5.828	1904 Jan. 21.201	0.92339	5.55377	0.714880	274 19 45	104 12 36	16 59 55	1903.0	Hillebrand, A. N. 163,301.
E. Swift (DeVico?)	6.400	1901 Feb. 13.671	1.66960	5.22478	0.515663	348 56 56	24 50 39	3 35 17	1900.0	Seares, A. N. 153,129;155,175.
Tempel1	6.538	1905 Apr. 20.463	2.09113	4.90201	0.401948	241 22 00	72 41 42	10 47 12	1905.0	Gautier, A. N. 167,396.
Finlay	6.556	1900 Feb. 16.697	0.96942	6.03616	0.723243	8 03 58	52 23 07	3 02 54	1899.0	Schulhof, B. A. XVI.
D'Arrest	6.686	1897 May 23.782	1.32701	5.77141	0.626113	319 26 20	146 25 11	15 42 32	1900.0	Leveau, B. A. XX, 312.
Biela Nucleus 1	6.693	1866 Jan. 25.584	0.87915	6.22289	0.752423	109 40 18	245 46 11	12 21 58	1866.1	Clausen, Annuaire 1905.
Biela Nucleus 2	6.693	1866 Jan. 27.461	0.87918	6.22404	0.752456	109 40 12	245 45 13	12 22 13	1866.1	Clausen, Annuaire 1905.
Wolf	6.823	1905 May 4.194	1.59527	5.59927	0.556533	19 19 38	206 29 00	25 14 40	1900.0	Thraen, A. N. 165,63.
Holmes	6.874	1899 Apr. 28.041	2.12773	5.10267	0.411448	345 46 53	331 42 54	20 48 08	1899.0	Zwiers, "Recherches sur l'orbite de la Comete Holmes," Leyden 1902.
Brooks (1889V)	7.100	1903 Dec. 6.318	1.95886	5.42934	0.469732	1 45 08	18 06 24	6 03 45	1903.0	Poor, Contrib. Obs. Columbia Univ. 22, p. 254.
Faye	7.390	1903 June 3.609	1.64972	5.93800	0.565160	45 26 48	206 28 00	10 37 30	1900.0	Strömgren, A. N. 161,320.

Comets of which only one Apparition has been Observed.

							°	′	″	°	′	″	°	′	″		
1819 IV (Blanpain)	4.810	1819	Nov.	20.252	0.89256	4.806	0.68675	67	18	48	77	13	57	9	01	16	1819	Encke.
1766 II (Helfenzrieder)	5.025	1766	Apr.	26.995	0.39898	5.468	0.86400	251	13	00	74	11	00	8	01	45	1766	Burckhardt.
1884 II (Barnard)	5.400	1884	Aug.	16.479	1.27975	4.87607	0.584214	306	10	58	5	08	59	5	27	38	1884.0	Berberich A. N. 123,175.
1844 I (DeVico)	5.459	1844	Sept.	2.484	1.18632	5.015	0.61737	342	30	48	63	49	38	2	54	46	1844.	Brünnow.
1886 IV (Brooks)	5.595	1886	June	6.685	1.32698	4.97660	0.578966	230	16	51	53	28	57	12	43	26	1886.0	Oppenheim, A. N. 128,302.
1770 I (Lexell)	5.626	1770	Aug.	13.547	0.67431	5.652	0.78684	356	16	27	131	59	34	1	34	31	1770	LeVerrier.
1783 (Pigott)	5.888	1783	Nov.	19.937	1.45929	5.062	0.55246	50	17	25	55	40	30	45	06	54	1783	C. H. F. Peters.
1890 VII (Spitaler)	6.420	1890	Oct.	26.119	1.81791	5.07783	0.472746	58	13	51	45	08	08	12	51	30	1891.0	Tennant, M. N. LII, 29.
1892 V (Barnard)	6.521	1892	Dec.	10.676	1.44220	5.54876	0.589683	16	31	28	206	30	57	31	16	19	1892.0	Coniel, B. A. June 1895.
1896 VII (Perrine)	6.526	1896	Nov.	24.668	1.11060	5.87368	0.681971	50	29	44	246	32	59	13	41	26	1897.0	Young, A. J. 17, 192.
1858 III (Tuttle)	6.609	1858	May	2.974	1.14922	5.894	0.67368	200	46	27	175	04	09	19	30	02	1858.0	Schulhof.
1896 V (Giacobini)	6.647	1896	Oct.	28.042	1.45475	5.61569	0.588500	334	00	55	193	29	04	11	21	48	1900.0	Ebell, A N. 161,139.
1900 III (Giacobini)	6.758	1900	Nov.	28.172	0.93328	6.21592	0.738922	7	55	39	196	36	12	29	52	16	1901 0	C. R. 133.
1905 II (Borrelly)	7.204	1905	Jan.	16.624	1.39830	6.06156	0.625110	68	50	54	76	38	05	30	33	53	1905.0	Wedemeyer, A. N. 168,139.
1895 II (Swift)	7.228	1902	Nov.	7.429	1.30472	6.17188	0.650986	338	15	49	170	16	56	3	00	43	1902.8	Schulhof, B. A. Sept. 1902.
1894 I (Denning)	7.418	1894	Feb.	10.454	1.14720	6.46022	0.698400	130	37	09	84	22	20	5	31	46	1894.0	Gast, Mitteil. Gr. Sternwarte in Heidelberg II.
1889 VI (Swift)	8.534	1889	Nov.	29.535	1.35368	6.99844	0.675849	40	15	02	330	36	02	10	14	54	1890.0	Hind, V. J. S. 27,68.
1881 V (Denning)	8.758	1890	May.	18.835	0.73587	7.76167	0.826805	18	03	06	65	30	01	6	55	26	1890.0	Matthiesen, A. N. 123,221.

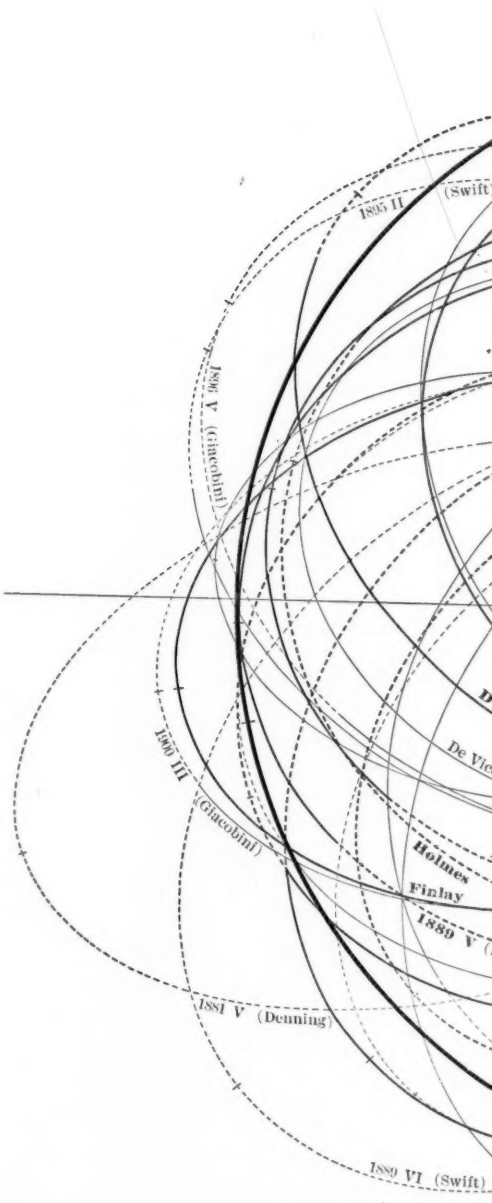
has gone over the accompanying table of elements of the comets of Jupiter's Family as carefully and critically as possible for him with all the past and recent data within our reach.

We are not sure that we have, in every instance, used the best elements for a few of the less important members of the family, because some sources of information may have escaped attention. If any astronomer should notice any important error in this regard, it will be esteemed a favor, if such error be pointed out and the better information be supplied.

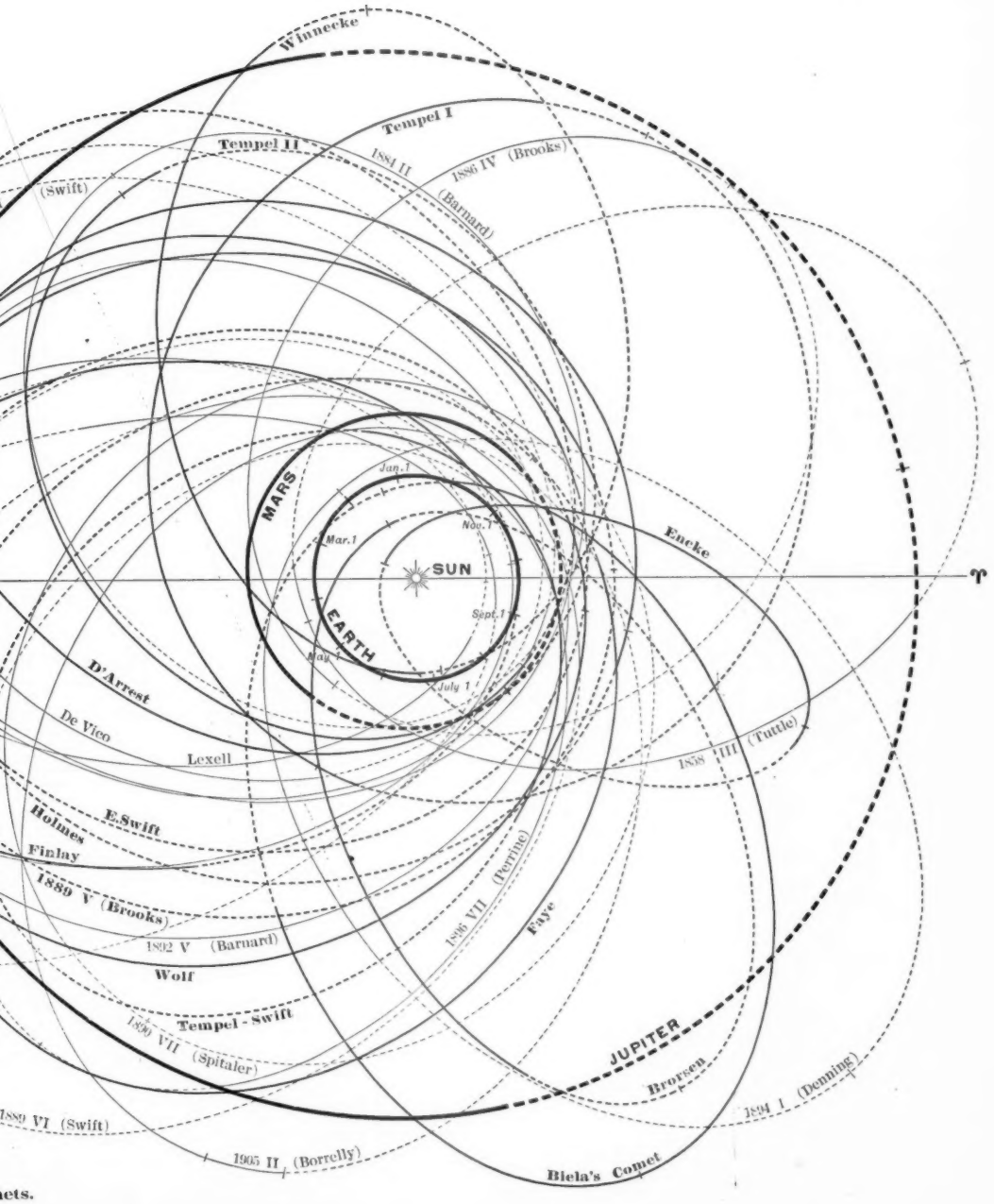
This notable family of comets is more and more a wonder, the further its study is pursued. Every student acquainted with the astronomy of the solar system knows that there is no other comet family that approaches this one in the number of its members, or in the strongly marked characteristics of the power of the planet Jupiter to capture comets and make them members of his family if they, in their wild flights through space, happen to come too near him in almost any part of his great orbital path around the Sun. By referring to the accompanying fine chart, the outer heavy circle will be at once recognized as Jupiter's orbit and the two inner heavy ones as those of the planet Mars and of the Earth.

By noticing the comet orbits carefully, it will be seen that some are made heavier than others. This distinction in the comet orbits themselves was not made in either of the former charts, and the purpose of it now is to show to the eye, at a glance, all those comets that have been observed at more than one apparition. Our chart may not be correct in one case, in this regard; and that is concerning the comets DeVico and E. Swift. In the French publication *Annuaire* of the Bureau of Longitudes, it is claimed that the comets DeVico and E. Swift are one and the same; but Dr. Sears in his investigations holds that the identity is not probable and his position seems to us the more reasonable one.

In Vol. I. of this publication we called attention to a few things which the chart shows that popular readers might readily grasp its meaning; such as the line through the middle of the plate which designates the line of the equinoxes, the sign Aries being to the right, indicating the direction of the vernal equinox. The top of the plate then is 90° in celestial longitude and the bottom, of course, is 270°. The Earth's orbit is made a solid ring because every part of it lies in the plane of the ecliptic. All other orbits are broken lines because they are inclined to the ecliptic. The dotted portions of all indicate the parts that are south of the



Jupiter's family of Comets.


Winnecke
Tempel I
Tempel II
1884 II
1886 IV (Brooks)
(Barnard)
(Swift)
MARS
Jan.1
Mar.1
Nov.1
SUN
Sept.1
EARTH
May 1
July 1
Encke
D'Arrest
De Vico
Lexell
1888 III (Tuttle)
E.Swift
Holmes
Finlay
1889 V (Brooks)
1892 V (Barnard)
Wolf
1896 VII (Perrine)
Faye
Tempel-Swift
1890 VII (Spitaler)
JUPITER
Brorsen
1894 I (Denning)
1889 VI (Swift)
1905 II (Borrelly)
Biela's Comet

nets.

ecliptic, while the continuous parts are in north latitude. The reader of the chart is supposed to be on the north side of the ecliptic looking down upon it. Now, notice these interesting facts.

1. That nearly all the farthest points of these comet orbits from the Sun (the aphelions) are on one side of Jupiter's orbit. These points in the comet orbits are generally marked by short cross-lines.

2. Notice where the dotted portions of the orbits join the continuous ones; when the comets moving in these orbits are respectively at these points they are then in the plane of the ecliptic, or at the nodes as the astronomer would say, and it is noteworthy that nearly all of them are quite close to Jupiter's path, so that the attraction of the planet must be considerable whenever it and the comets are near these nodal points at the same time. The law is that celestial bodies attract one another directly as their masses and inversely as the square of the distances between their centers. The mass of Jupiter is about 318 times that of the Earth, and about one one-thousandth part of that of the Sun. But the average mass of the comets can not be more than one one-hundred thousandth part of the Earth's mass; that would be as Young declares about equal to ten times the mass of the Earth's atmosphere. Now if the mass of Jupiter is 318 times that of the Earth, and the Sun's mass is 1000 times that of Jupiter, it is easy to see why the aphelion points of all the comets Jupiter can capture are placed near his path while all the perihelion points of the comet paths that Jupiter can control must be crowded together near the Sun. A look at the chart with this thought in mind gives to it impressive meaning, and one might be led to say, the wonder is that Jupiter does not hurl them all headlong into the Sun, and thus violently put an end to all foreigners who trespass on his power of eminent domain. This interesting and natural thought is limited by a more careful and exact study of mass, velocity and what is called "domain" of the planets. The astronomer knows that within a radius of about 15,000,000 miles Jupiter has greater attraction than the Sun, but the velocity of the comet caused by the attraction of the Sun when it is at the distance of Jupiter and moving in a parabolic orbit is eleven miles per second; but if Jupiter should capture the same comet and cause it to move in a circular orbit, the motion of the comet would be reduced from eleven miles to eight miles per second. The orbits of the comets in the Jupiter Family are all elliptical and their respective velocities would vary somewhat at the aphelion points, though not greatly because

their periods of revolution on the average are about half that of Jupiter. Much more might be said on this point; but space forbids.

3. We reprint the following from Vol. 1 page 25.

"The Sun and the whole solar system is moving through space towards a point in the Constellation ofHercules, having a right ascension of 267° and a declination north 31°. Now notice that the bottom of the plate is right ascension (or longitude) 270° and that direction is the way the solar system and all belonging to it are drifting in space at a probable rate of sixteen miles per second continually. If Jupiter obtained his family by capture, why should he be more successful on one side of the orbit than on the other?

4. The motions of these bodies about the Sun are direct the same as planets, *i. e.*, contrary to those of the hands of a watch. Jupiter's orbital velocity is eight miles per second, hence on one side of his orbit he is moving in space at the rate of more than twenty miles a second, while on the other it would be about eight. Probably Jupiter will meet or overtake more comets and influence their courses at the former rate than at the latter, especially if we think of comets generally moving through space, in any direction, and at the distance of Jupiter from the Sun, as having an average velocity of eleven miles a second."

Those who desire to study the method of construction of the orbits of this comet family, will find full instruction how to do this work in Vol. 1 of this publication, p. 62. The method is an excellent one and due to Professor William Harkness of the United States Naval Observatory, Washington, D. C., which was prepared for, and first published in the December number of the *Sidereal Messenger* in 1887. In that article the work was so carefully and thoroughly done that it has been republished without verbal changes.

PHOTOMETRIC DETERMINATION OF THE STELLAR MAGNITUDE OF THE SUN.*

W. CERASKI.

The definition of the stellar magnitude of the Sun, or in other words the determination of the quantity of light which the Sun sends us compared with this or that star, is of considerable im-

* Translated by Miss Isabella Watson, Northfield, Minn.

portance in astronomy, analogous for instance, to the determination of the annual parallax; and it presents great difficulties.

In the spring of 1903, Venus being in a position very convenient for these observations, I resolved to undertake, through the medium of this planet, the comparison of the brightness of the Sun with that of a star.

The detailed account of my research which was pursued with particular care, is to appear in the Annals of the Observatory of Moscow; it contains the determination of the coefficients which intervene, the enumeration of precautions taken to avoid errors coming from widely different sources, and the separate results.

At this time I will give in a few words a brief description of the method employed and the final result. During the day I compared the reflection of the Sun with Venus. The Sun's rays were reflected from the anterior surface of a lens mounted on the summit of the meteorological tower which stands opposite our observatory. I obtained: $\log \frac{\odot}{\varphi\, 112} = 9.1790$ where $\odot$ denotes the intensity of the Sun at the unity of the distance and φ 112 denotes that of Venus 112 days before its inferior conjunction. After sunset Venus was compared photometrically with α Leonis. It was a great surprise to me that this part of the work presented almost insurmountable difficulties. Against the bright background of the twilight glow α Leonis appeared as a luminous point, twinkling very much and of exceedingly small diameter, while Venus shown with clear and steady brilliancy so that the photometric comparison was made very difficult and there was no possibility of obtaining a good determination. These observations among others made it obvious to what degree the influence of the background is eliminated in the photometer of Zöllner, for the readings of the circle for Venus were the same in the day time and at night within the limits of ordinary discordances although the planet presented itself under entirely different aspects.

Toward spring of the present year Venus was again in a position favorable for research of that kind: this time one might hope to reach much more definite results and I could not miss this opportunity of doing over again the second part of my study. Indeed the observations were much more convenient and more exact; only the phase of Venus was already a little too small, but being scarcely perceptible in the little telescope with which I was working, that was of no importance.

I found:

$$\log \frac{\varphi 112}{\text{Polaris}} = 2.2842 \text{ (4 days' observations)}$$

$$\log \frac{\varphi 112}{\alpha \text{ Canis min.}} = 1.7110 \text{ (4 days' observations)}$$

$$\log \frac{\varphi 112}{\text{Sirius}} = 1.0526 \text{ (only one day)}$$

It follows that

$$\log \frac{\odot}{\text{Polaris}} = 11.4632$$

$$\log \frac{\odot}{\alpha \text{ Canis min.}} = 10.8900$$

$$\log \frac{\odot}{\text{Sirius}} = 10.2316$$

That is to say that the Sun sends us

290,550,000,000 times more light than Polaris
77,630,000,000 " " " " α Canis min.
17,045,000,000 " " " " Sirius

Taking for the magnitudes of these stars 2.15, 0.56, — 1.09 (Potsdam), we shall have for the stellar magnitude of the Sun

26.51, 26.66, 26.67.

One usually gives a minus sign to the magnitudes of stars superior to first magnitude, but it seems to me almost paradoxical to assign a negative value to the magnitude of the Sun, which is, so to speak, the most positive quantity that one can imagine; accordingly I take the liberty of calling it supermagnitude.

By taking the average of the values given above and considering the weights, we will say that the Sun is 29.59 supermagnitude.

Moscow, August 20,-September 2, 1905.

THE SOLAR ORIGIN OF TERRESTRIAL MAGNETIC DISTURBANCES.*

E. WALTER MAUNDER, F. R. A. S.

In the last number of the "Journal" there is a report of the address delivered by the President of the New South Wales Branch of our Association, Mr. G. D. Hirst, F. R. A. S., at the Annual Meeting of the Branch held on October 17th, 1905. In the course of his address Mr. Hirst made a reference to the paper on the solar origin of terrestrial magnetic disturbances which I communicated to the Royal Astronomical Society in November 1904. Unfortunately, if Mr. Hirst is correctly reported, he has formed an altogether mistaken conception of the purport and results of

* *Journal of the British Astronomical Association*, February.

my paper, and I should like, if it is agreeable to the Association, to be permitted to make a few remarks upon the subject.

Mr. Hirst's description of my paper is as follows:—

> Mr. Maunder's theory in brief is, that there is a magnetic meridian on the Sun, which has an influence in producing magnetic disturbances on the earth, when presented to it, and that, when sun-spots occur at or near this meridian, the disturbance increases to a magnetic storm. Mr. Maunder makes out a fairly strong case for his theory and supports it with many data, but it has been subjected to some strong criticism and it would be perhaps as well to suspend judgment pending further researches upon this most interesting subject. "Journal," Vol. XVI., No. 3, p. 98.

What I actually did, in the papers to which Mr. Hirst refers, was this. I made two catalogues, the first ranging from 1882 to 1903, the second from 1848 to 1881, containing all the principal magnetic disturbances that had been recorded at Greenwich during those periods. There were 276 such disturbances in the first catalogue, 450 in the second. That was the first stage of my work. I should remark that the selection of the disturbances had been made (chiefly by Mr. Ellis) long before I engaged in this inquiry, and therefore quite independently of it.

My next step was one of simple computation. Adopting Carrington's formula, I computed the heliographic longitude of the centre of the Sun's disc for the time of commencement of each of these disturbances.

The third step was to point out a fact which became obvious directly this computation had been made, namely, that there was a strongly marked tendency when a magnetic disturbance had occurred or another to follow it when the same longitude had returned to the centre of the Sun's apparent disc.

The fourth step was to inquire whether this happened more frequently than could be fairly attributed to accident. I showed that some of these instances of recurrence were so strongly marked that the chances against their being accidental ran into the millions. This demonstration was much bettered by Prof. F. W. Dyson*, who pointed out that in my first catalogue there were 49 pairs of consecutive rotations of the Sun, in each of which one and only one storm occurred. Of these 49 pairs, 18 gave the second disturbance corresponding to the same longitude within 10° as the first. Now, Prof. Dyson showed that the chance of as many as 18 such pairs occurring fortuitously is only 1 in 20,000 millions. This does not exhaust the evidence supplied by this first

* "Observatory" for 1905, Vol. XXVIII., p. 176.

catalogue of a real connection between our magnetic disturbances and of the solar rotation, but is quite sufficient to take it entirely out of the region of uncertainty.

So far at least there was nothing in the way of theory or speculation in my paper. So far too the paper has stood absolutely unchallenged. No one has attempted to show that my catalogue was incorrect. No one has called in question the accuracy of my computation of the heliographic longitude. No one can dispute that there are numerous instances in the catalogue of the recurrence of similar longitudes—what for the sake of distinctness I have called "sequences." No one has impugned Prof. Dyson's computation of the chances of accident.

My paper, therefore, stands so far entirely without challenge, and its result up to this point, a result merely of direct observation and simple computation, is that there is an evident connection, far too strongly marked to be fortuitous, between the solar rotation and the times of occurrence of our magnetic disturbances.

What is the deduction which we must make from this? Clearly there must be some action from the Sun which occasions our disturbances. Is this action from the Sun as a whole? If so, then we must suppose that from time to time some sort of cataclysm takes place all over the Sun, which has a strongly marked tendency to repeat itself whenever the solar longitude which had the Earth in its zenith at the time of the first cataclysm comes again in the same position relatively to the Earth.

Now, such an idea is frankly absurd. The only alternative is to suppose that the solar action, whatever its nature, does not arise from the entire surface of the Sun but from a portion only—from what I have called a "restricted area" is brought by the solar rotation a second time into the same position relatively to the Earth.

There is a further consequence. The mode in which the solar activity—whatever its nature—that occasions the terrestrial disturbances travels to the Earth cannot be by a radiation in all directions, but must be confined to a particular direction. This we are assured of, because if we had a radiation from these "restricted areas" which, as in some way giving rise to our magnetic disturbances, I may be permitted to call "magnetic areas," then our disturbances would commence directly a magnetic area reached the E. limb of the Sun, and would continue until it has passed off at the W. limb. In other words, the general duration of a disturbance would be about a fortnight, that is to say, half

the synodic rotation period of the Sun, and when a disturbance recurred, it would be at the expiration of a half-rotation period from the end of the preceding disturbance. There is no approach to any such an arrangement, and we, therefore, know that the solar action reaches us along definite or restricted lines, not by any general radiation in all directions through space. Of course in the above remarks I am leaving out of consideration two points: first, the time taken by the solar action to travel to the Earth, and next, the time which the disturbance would take in settling down after the disturbing action ceased to be felt. But the former would occasion just the same delay in the arrival at the Earth of the last impulses felt as of the first, and so leave the *relative* times of the two unaltered. Whilst the second could only operate to prolong the disturbance, and so to make the time of activity for any recurring disturbance longer than the time of rest.

There is a fourth point. Since the Earth has a very small angular diameter as seen from the Sun, only 17″.6 of arc, and as these "stream lines"—if I may so term these lines, restricted in direction, along which the solar action reaches us—cannot be of indefinite breadth, many of them must miss the Earth altogether. Only some, therefore, of the areas upon the Sun which are potentially competent to bring about a magnetic disturbance on the Earth, actually do so.

Fifth. As the solar rotation period is 25.2 days, and the Earth's period of revolution in its orbit is 365.25 days, it follows that a "stream line" from the Sun must overtake the Earth in its orbit. It will, therefore, strike it first on the sunset arc, that is to say, along that half of the circumference of the Earth, as viewed from the Sun, which is on the following side.

These five conclusions are simple, direct, inevitable conclusions from the observed relation to one another of the times of our magnetic disturbances. There is no speculation in all this; there is no theory. I have offered no suggestion as to the mode of the original solar action, as to its transmission along the restricted lines, as to the nature of its operation upon the Earth's magnetism, or as to the source of the energy evidenced in those disturbances. All these questions I have left severely alone, but nevertheless, as it is, my papers have made a revolution in this particular department of solar and terrestrial physics.

Until my first paper appeared it was generally held that there were only two possible alternatives.

There is no connection between any solar activity and our magnetic disturbances,

or,

The solar action, giving rise to those disturbances, comes from the Sun as a whole and is radiated in all directions through space.

Now, it has been shown that our magnetic disturbances themselves have characteristics which prove indubitably—

(1) That they are connected with the Sun;

(2) That the Sun's action, of whatever nature, is not from the Sun as a whole, but from restricted areas;

(3) That the Sun's action is not radiated, but restricted in direction.

This new view has been accepted, explicitly by many, implicitly by all. For there is no scientific man who has a reputation to lose who will to-day base a paper upon those ideas which were currently accepted before my paper appeared.

The foregoing gives the central and most important result of my inquiry. My catalogue, however, brought into evidence some further peculiarities of our magnetic disturbances which justify the title which I adopted for my papers of "Magnetic Disturbances and their Association with Sun-spots." I adopted this title in the first place, because the earliest stage in my work, when as yet I had not the slightest foreshadowing of the results to which I would be led, consisted of an attempt to trace a connection between certain particular sun-spots and certain particular magnetic storms. ("Monthly Notices," R. A. S., Vol. LXIV., p. 205.) As I have already said, in drawing up my catalogues of disturbances, I gave not only the approximate Greenwich day and hour at which the magnetic disturbances began, but I also gave the heliographic longitude of the centre of the Sun's disc at those times, and for brevity and distinctness I referred to the longitudes thus determined as "magnetic" longitudes. This was a more accurate method of presenting the intervals, since the Sun's synodic rotation period appears to vary during the course of a year owing to the varying rate of the Earth's motion in its orbit. I was very far from assuming or asserting that it was the meridian then at the centre of the Sun's disc that produced any particular magnetic disturbance; much less that "*a magnetic meridian on the Sun*," as Mr. Hirst expresses it, produced all or the majority of terrestrial disturbances. I have since had occasion to point out, as I had recognized more than

20 years ago, that Carrington's rotation period, which has been generally adopted and used in this country, is a convenient one, but does not accurately represent the mean period of the Sun as deduced from all sun-spots, and is very far from representing the rotation periods of particular spots which may be found in any latitude on the Sun. But this is far from being an argument against the connection between the Sun's rotation and terrestrial magnetic disturbances, for, as I have shown, the irregularities in the longitudes of the centre of the Sun's disc, as given by the different "sequences" of magnetic disturbances, are strictly analogous both as to character and amount with the irregularities in the longitudes of sun-spots.

This similarity in the behavior of these "magnetic longitudes"—that is to say, the longitude of the center of the Sun's disc at the time when the beginning of a magnetic disturbance is noted—and of long-enduring spot groups does, I think, amply justify us in regarding sun-spots and disturbances as being in some way associated. But even here, as I have pointed out on not a few occasions during the last 20 years, though sun-spots are the solar phenomena which are most easily and most continuously observed, though they are indeed the only phenomena of which we have as yet sufficient observations to enable us to satisfactorily compare them with our magnetic disturbances, they are not, therefore, necessarily in themselves the most significant forms of solar activity.

Beside the foregoing results, which are, as I have said, direct and inevitable conclusions from observation, certain other conclusions were suggested by my catalogues of disturbances. I was very careful to draw a broad distinction between the two, between the points already laid down, which were inevitable conclusions, and other deductions for which as yet the evidence was not yet absolutely complete. My catalogues of disturbances suggest that the restricted areas giving rise to those disturbances are not scattered indiscriminately over the Sun's surface, but have a tendency to concentrate in certain regions, and I drew attention to the fact* that the great sun-spot of February 1892 synchronised both at its February and at its March apparition with a great disturbance, and that the longitude of the centre of the disc when those two great storms occurred was more frequently associated with magnetic disturbances than any other in the whole catalogue from 1882 to 1903. It should be also

* "Observatory" for 1904, December, Vol. XXVII., p. 432.

noted that the region where this great sun-spot formed was, as Father Cortie has pointed out, the seat of the most continuous sun-spot action in the whole cycle 1889-1901. This suggestion is only a specimen of the work which yet remains to be done in the association of *particular* sun-spots with *particular* storms; that inquiry is yet in embryo. But whether such an association between *particular* phenomena can be established or not, it can not affect in the slightest the conclusions which have been reached concerning the solar origin of our magnetic disturbances. "If the Sun had never shown one single marking on disc or limb, the conclusion would still be inevitable, provided only we knew the rotation period of the Sun, which the spectroscopic method might still have given us. It rests simply upon the times at which successive magnetic disturbances commence. If the Sun's surface were absolutely undiversified, we should still know that certain restricted regions of it were capable of exercising this influence upon our Earth, although we had no other indication of any special action there taking place."*

There is just one further point upon which I would like to touch. Mr. Hirst says that my paper "has been subjected to some strong criticisms." Dr. Schuster contributed a highly interesting paper to the "Monthly Notices," but I think I am warranted in saying that it was intended to be a parallel discussion of the question from a different point of view, and by no means in opposition to my paper; he certainly endorsed my conclusions. Dr. Chree, who is necessarily an authority of the first rank in the matter, has written two lengthy papers, in which he reserves his judgment, but these are the only papers which are in any way criticisms of my research.

Three points which Dr. Chree raised call for consideration. First, he objected that the classification of the disturbances was an arbitrary one, and further that the annual and cyclical inequalities would materially affect that classification. The next point was that there was considerable uncertainty in the times of commencement of most disturbances; and, thirdly, that the estimation of these times of commencement was liable to be affected by diurnal inequalities.

These are, however, all abstract objections, which have no real bearing on the concrete case, and it is most significant that Dr. Chree, than whom there is no man better acquainted with the magnetic records, not of one place only, but of observations

* "Monthly Notices" for 1904, November, Vol. LXV., p. 22.

the world over, has not attempted to show that any of these three criticisms has the slighest practical bearing upon the tendency of magnetic disturbances to run in "sequences" corresponding to the synodic rotation periods indicated by sun-spots.

Two or three actual examples will show better than much discussion how perfectly wide of the mark all these three objections are. Of the three following tables, Table I. gives the dates of the 20 greatest storms in the quarter of a century beginning with 1869. The choice of these 20 is practically independent of any system of classification, since they stand out undeniably as the giants of their kind. It is, of course, quite, possible that three or four more storms might be selected in the same period almost, or perhaps quite, as pronounced as the least intense of these, but their exclusion or inclusion cannot substantially affect the argument which the catalogue presents. Certainly the ranking of the above 20 disturbances as great storms is altogether independent of consideration of the annual or cyclical inequalities. So too the times of their commencement are independent of the effect of diurnal inequalities, and of the difficulty frequently felt of estimating the exact hour when a storm begins. For on the one hand all the 20 began with the typical "sharp" movement, and on the other the argument to be drawn from the table remains unaltered if we cancel the hours and retain only the days.

For what does the table show? If we take the intervals between the two successive storms, we find that one interval is repeated four times, and no other interval is repeated at all. In other words, that 8 out of the 20 storms catalogued are arranged in pairs, and the members of these pairs are separated by an interval which corresponds closely to the mean synodic rotation period of the Sun.

Let us put it in another way. The total period covered by the catalogue is 335 solar rotations; the maximum range of the interval is under $^1/_{30}$ of a rotation period. As this variation from the mean may take place in either direction, we may consider each rotation as divided into 15 equal parts, making 5,025 parts for the entire period. The question is, if the 20 storms happened at random, what is the chance that 8 of the 20 should fall in pairs a rotation apart, within this limit of a $^1/_{30}$ of a rotation either way. It might be parallel by the case of a library of 5,025 books, of which 20 books were bound in red*; the whole being

* See Mr. Newall's analogy; "Observatory," Vol. XXVIII., p. 89.

distributed over 335 shelves with 15 books on each shelf. What is the chance that eight out of the 20 red-bound books would be arranged in four pairs of which one book was *precisely and immediately* over the other.

We may consider 16 of the storms as already fixed on us; the other 4 then must take their places, each in a particular relation to some one of the 16 storms already placed. There are 5,009 places vacant for the 17th storm, 32 of which would enable it to form a pair with one of the 16. Similarly, there will be 5,008 places vacant for the 18th storm, of which 30 would enable it to form a pair with one of the 15 storms, and so on; with the result that it is nearly 900 millions to 1 against such an arrangement, as that which we actually have, being due to pure accident.

Tables II. and III. are taken from the same period of time from the published records of the Stonyhurst and Bombay observatories respectively. Each day has been ranked according to the best judgment of the Director of the observatory as a day of "very great," "great," or "moderate" disturbance. The observations are ranged so that a day in one line is immediately above a day 27 days later in the next, but 31 days are given in any one particular line, so as to afford a little overlapping. The date of the first day in each line is printed at the beginning of the line. Days of disturbance common to both observatories are printed in Roman type; if observed only at one observatory, in *italics*.

In this case no question of the effect of any diurnal inequality, or of the difficulty of fixing the precise hour of commencement, enters into consideration. Further, the two observatories are far apart and their records are entirely independent. Yet it will be seen that they are in exceedingly close agreement, allowing for the fact that disturbances of the intensity selected are some what more frequent at Stonyhurst than at Bombay. Both observatories show alike a very strongly marked tendency for the disturbances to run in "sequence." Evidence of this kind could be multiplied indefinitely. Take magnetic disturbances as you will, their tendency to recur at intervals corresponding to the solar rotation period becomes obvious at once.

How is it that a relation so simple and obvious, and with such important consequences, was not discovered long before? Partly because the attention of magnetic observers has been directed to exhibiting means and to eliminating the effect of disturbances, so that the reports of magnetic observatories may be collected by the score in which there is not the slightest allusion to a disturbance from cover to cover. There have been several cases in

which attention has been drawn to a period of very nearly 27 days, but it is significant that the observers who have recognized this period—Quetelet, Veeder, Clough and Harvey—have all been observers of auroræ rather than of terresterial magnetism, and it was from auroræ that they learnt to recognize the recurrence of this interval. This, no doubt, explains why so little attention was paid in general to their conclusions. There was a feeling, justifiable to some extent, that our observations of auroræ were too indefinite, too much affected by local conditions to warrant any important inference being based upon them. In any case the evidence furnished by auroræ is far from being so strong as that furnished by magnetic disturbances.

On the other hand many magnetic observers have given no attention to solar physics and the occurrence of a period of about 27 days would suggest to them rather some connection with the Moon than with the solar rotation. The paper by James Allan Broun in "The Philosophical Transactions," 1876, is particularly interesting in this connection. Though he dealt with the records of only two years, he had sufficient material to demonstrate the connection, and he pointed the conclusion with very great clearness. Apparently, however, the fact that he had assumed a wrong value for the solar rotation, and that he was hampered with preconceived ideas concerning the action of the Moon, prevented him from attaching any value himself to the result which he obtained, and by consequence rendered it valueless in the sight of others.

TABLE I.

Great Magnetic Storms, 1869-1893.

	d	h		d	h
1869, April	14	23.5	1881, Jan.	30	20.8
May	13	1.6	1882, April	16	23.5
1870, Sept.	23	14.6		20	3.6
Oct.	23	21.9	Nov.	17	10.3
1871, June	17	11.6	1886, Mar.	30	8.2
Nov.	1	6.0	1892, Feb.	13	5.5
1872, Feb.	4	2.4	Mar.	11	22.5
July	7	5 0	May	18	8.4
Aug.	3	3.8	July	16	12.6
Oct.	14	10.3	Aug.	12	12.6

TABLE II.

Magnetic Observations at Stonyhurst, arranged to show 27-day periods.

1895.

| | | |

1896.	
Jan. 25	MMMMMM MM
Feb. 21	*MM* G M G *MM* *MM*
Mar. 19	MMM M
Apr. 15	MMMMM VV M
May 12	M MM*MMMM* MM
June 8	MM M M MMMM*M*
July 5	MMM*M* M *MM* MMM
Aug. 1	MMM MM*MM* M M M
" 28	M M VV M
Sept. 24	M *M* M G G M
Oct. 21	MMMMM
Nov. 17	MM M *M*
Dec. 14	*M* M G M

TABLE III.

Magnetic Observations at Bombay arranged to show 27-day periods.

1895	
Aug. 16	*M* M
Sept. 12	M M MMM M
Oct. 9	MM MM MMMM M
Nov. 5	M G G MM MM
Dec. 2	G M M M
" 29	MMMMMM M *M* M MM
1896	
Jan. 25	MMMMMM MM
Feb. 21	G M G M M
Mar. 19	MMM M
Apr. 15	MMMMM VV M
May 12	M MM M MM
June 8	MM M M MMMM
July 5	MM M M M *M* MMM
Aug. 1	MMM MM M M M
" 28	M M M V M
Sept. 24	M MMGGM
Oct. 21	MGGMM
Nov. 17	MM M
Dec. 14	MGM *M*

PROFESSOR WILSON'S LIST OF ALGOL VARIABLES.

F. H. SEARES.

FOR POPULAR ASTRONOMY.

An examination of the "Revised List of Variables of the Algol Type" given by Professor Wilson in *Popular Astronomy* for February 1906. p. 76, has revealed a number of errors and omissions which impair to a certain extent the usefulness of the list. The corrections, so far as noted, are collected below for the convenience of those who have occasion to use such a list. In general, the elements and positions have not been verified, so that the data given below refer mainly to the question as to whether or not certain objects should be included in the list of Algol variables. The changes required are as follows:

The stars RU Lyrae, S Antliæ, and W Ursae Majoris should be stricken from the list of Algol variables.

RV Lyrae, RU Monocerotis, U Scuti, RW Tauri, and RR Draconis should be added to this list.

Apparently RU Lyrae and RV Lyrae have been confused with each other, for Professor Wilson's list contains the name and position of the former, a variable of continuous variation, associated with the elements of the latter, which is really of the Algol type.

S Antliæ was discovered by Paul in 1888 (A. J. No. 215). Its variability was confirmed by Sawyer, Chandler and Yendell, (A. J. Nos. 215, 216, 218), all of whom classed it as an Algol variable. But in H. C. O. Circular No.7 Pickering called attention to the fact that the period of maximum brightness is less than one-half the total period, and that it is difficult to reconcile this fact with an assumption of Algol variability. Pickering's conclusion was that the star varies continuously, with a very slow rate of change in the neighborhood of the maximum. This conclusion was confirmed by photometric observations made at Cambridge, (A. N. No. 3385), and has received further confirmation by the observations of Sperra (A. J. No. 413) and Luizet (A. N. No. 3955). Chandler classed the star with the Algol variables in the Second and Third Catalogues, but in his "Revision of Elements of the Third Catalogue of Variable Stars," (A. J. No. 553), he omits the designation of "Algol type." The star first appears in the Hartwig "Ephemeriden" for 1902 as No. 549, where it is designated as "short period."

W. Ursæ Majoris is clearly a case of continuous variability as is shown by the observations of Müller and Kempf, (Sitzungsberichte der Kgl. Preuss. Akad. der Wiss., 1903, p. 181, A. P. J., v. 17, p. 201). The characteristic features of the light curve revealed by the observations of the discoverers are reproduced in that recently derived by Parkhurst from photographic observations, (A. P. J. v. 23, p. 83). The star is of unusual interest on account of its period which is only four hours.

As for the Algol stars which have been omitted from the list, RV Lyræ has already been mentioned. Its position for 1900 is $19^h\ 12^m\ 30^s + 32°\ 14'.6$. RU Monocerotis was discovered by Madame Ceraski in 1905, (A. N. No. 4003). Its position for 1900 is $6^h\ 49^m\ 24^s - 7°\ 28.'2$. Its range of variation is from 9.8 to 10.5 magnitudes. Six or seven hours are required for the light change while the period is 21.8 hours.

U Scuti was announced as an Algol variable by Professor

Ceraski in 1901, (A. N. No. 3718), and bears the number Ch 6773. Its position for 1900 is $18^h\ 48^m\ 52^s - 12°\ 43'.8$. The range of variation is from 9.1 to 9.6 magnitudes and its period is $22^h\ 55^m.2$.

RW Tauri and RR Draconis are both Algol variables of unusual interest on account of their range of variation which amounts to nearly four magnitudes. The former discovered by Mrs. Fleming, (H. C. O. Circular No. 104; A. N. No. 4047), varies from the seventh to the eleventh magnitudes and has a period of 2.76886 days. Its position for 1900 is $3^h\ 57^m\ 45^s + 27°\ 51'.0$.

RR Draconis was discovered by Madame Ceraski in 1904, (A. N. No. 3987) and early observations at Moscow suggested a variation of the Algol type. Observations made at the Laws Observatory from June to October 1905 confirmed this suspicion and gave for the period $2^d\ 19^h\ 56^m\ 44^s$ with an uncertainty of 5 seconds. The elements resulting from these observations are

$$m = \text{J. D. } 2416766.229 + 2.83107\ E.$$

At normal brightness the star is 0.3 magnitude fainter than B. D. $+ 62°.1639$ (9.3). The Laws Observatory observations leave the minimum brightness uncertain, as the star is invisible in the 7½-inch equatorial for a period of about two hours in the neighborhood of the minimum; but when faintest, it is probably near the 13th magnitude. These results, together with an ephemeris of minima, were announced in Laws Observatory Bulletin No. 6, 1905, Nov. 3, and are confirmed by the data given by Hartwig in the "Ephemeriden," for 1906, derived apparently from observations made at Moscow. The period given by Hartwig is $2^d\ 19^h\ 56^m\ 48^s$. The epochs derived from the two sets of elements for the first minimum of 1906 differs by only 3^m. The position of the star for 1900 is $18^h\ 40^m\ 49^s + 62°\ 34'.5$. It will be observed that the two objects RW Tauri and RR Draconis present light curves which are very similar in so far as range and period are concerned.

The five stars RV Lyrae, RU Monocerotis, U Scuti, RW Tauri, and RR Draconis are respectively Nos. 339, 113, 313, 58, and 308 of the Hartwig "Ephemeriden" for 1906. Each of these objects is there classed with the Algol variables, and an ephemeris of minima is given for each.

Although the other lists given by Professor Wilson have not been specially examined, it may be remarked that the star U Pegasi should not appear in the list of Antalgol stars. There is some difference of opinion as to the exact nature of its light curve, but certainly it is not of the Antalgol type. Pickering maintains, and with a good showing of evidence, that the star varies continuously and has unequal minima; in other words, that it is of the β Lyræ type, (H. C. O. Circular Nos. 23, 25).

But, inasmuch as the difference between the successive minima derived from the observations of Wendell amounts to only 0.15 magnitude, Chandler prefers to regard the star as of the ordinary short period continuous variation type until the results of the Cambridge observations shall have been confirmed elsewhere, (A. J. No. 426). In the meantime, there is a corresponding uncertainty in the period, which is $8^h\ 59^m\ 41^s$ provided the conclusion of Pickering be accepted, or one-half of this amount, if the assumption of equal minima be admitted.

Columbia, Missouri, 1906, March 14.

PLANET NOTES FOR MAY, 1906.

H. C. WILSON.

THE CONSTELLATIONS AT 9 P. M. May 1, 1906.

Mercury will be at greatest elongation, west from the Sun 26° 46′, on May 2 and so will be visible as morning star during the first week in May. There will then be no bright stars in the vicinity of Mercury, so that if the observer sees a bright star near the eastern horizon about an hour before sunrise he may be pretty sure that he has found the planet.

Venus is evening star, and on May 1 will be just south of the Pleiades, setting in the northwest about two hours after the Sun. On the evening of May 11 Venus and Jupiter will be in conjunction in right ascension, Venus being then 1° 11′ north of Jupiter. The two planets will be near enough to each other to be seen at the same time in the field of a small telescope.

Mars is also in the same vicinity and on the morning of May 6 Venus and Mars will be in conjunction, Venus being only 5′ south of Mars at the time of nearest approach. Mars and Jupiter also come into conjunction on the morning of May 18, Mars being then 1° 6′ north of Jupiter.

Jupiter has been the monarch of the evening sky during the winter and spring but must now give place to Venus. The three planets Venus, Mars and Jupiter with the red star Aldebaran will form an interesting group in the western evening sky during the first half of May. All however, will be at too low an altitude, when visible, for satisfactory observation with the telescope.

Saturn is on the other side of the Sun and is visible in the morning hours, in the constellation Aquarius.

Uranus too may be seen in the morning, but requires the use of a telescope. It is near the lowest point of the ecliptic in the constellation Sagittarius.

Neptune is to be found with the aid of a telescope in the constellation Gemini about four degrees east from the star μ.

Occultations visible at Washington.

Date 1906.	Star's Name	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle f'm N pt.	EMERSION. Washington M.T.	EMERSION. Angle f'm N pt.	Duration.
			h m	°	h m	°	h m.
May 2	ν Leonis	5.0	5 17	144	5 33	158	0 16
2	a Leonis	1.4	11 42	78	12 33	325	0 51
3	x Leonis	4.6	13 36	131	14 29	271	0 53
6	80 Virginis	5.6	4 49	111	5 44	294	0 55
6	n Virginis	6.5	11 55	87	12 59	325	1 4
8	Bradley 1987	6.5	9 7	51	9 38	354	0 31
8	η Librae	5.5	10 4	196	10 13	210	0 9
11	ξ Sagittari	5.1	11 35	74	12 39	298	1 4
13	21 Capricorni	6.5	14 37	94	15 55	244	1 18
29	ψ Leonis	5.6	6 6	96	7 24	311	1 18

COMET NOTES.

New Comet *b* 1906 (Kopff.)—A telegram from Harvard College Observatory, March 5, announces the discovery of a faint comet by Kopff, of Heidelberg, on March 3.

The discovery position is

March 3.596 Greenwich M. T. R. A. $11^h\ 36^m\ 56^s$, Decl. $+\ 1°\ 40'$.

The comet is in the southeastern corner of the constellation Leo and is moving very slowly northwest.

Preliminary elements and ephemerides have been received as follows:

ELEMENTS.

Computer	Dr. Ebell at Kiel	R. T. Crawford and A. J. Champreux
T	1906 Jan. 4.09 Gr. M. T.	1905 Dec. 25.1660 Gr. M. T.
ω	138° 25′	143° 42′.7
Ω	328 24	329 22 .3 1906.0
i	0 54	1 08 .5
q	1.0841	1.31149

Ephemeris from Dr. Ebell's Elements.

Gr. M. T. 1906	R. A. h m s	Dec. ° ′	Light
Mar. 11.5	11 32 44	+1 51	0.66
15.5	11 31 20	+1 57	
19.5	11 30 08	+2 02	
23.5	11 29 16	+2 06	0.34

Ephemeris from Crawford and Champreux's Elements.

Gr. M. T. 1906	R. A. h m s	Dec. ° ′	Light	log Δ
Mar. 9.5	11 33 34	+1 48.3	0.91	9.8528
13.5	11 31 46	+1 54.4		9.8729
17.5	11 30 17	+2 00.3		9.8940
21.5	11 29 00	+2 05.5	0.60	9.9158

Brightness March 6 = 1.00

New Comet *c* 1906.—A telegram received from Harvard College Observatory March 19, announces the discovery of a small telescopic comet by Ross at Melbourne on March 18. The discovery position is given as

Mar. 17. 914 Greenwich M. T. R.A. = $2^h\ 03^m\ 52^s$, Decl. = $-7°\ 41'$.

This places the new comet in the constellation Cetus, about 5° south and a little west of the well known variable star *o* Ceti. The daily motion is given as $+3^m\ 36^s$ in R.A. and $+70'$ in Decl.

The physical appearance of the comet is described as: circular, 3′ in the diameter, magnitude 8, some central condensation.

The following observation is all that has come to hand as we go to press.

Gr. M. T.	R. A.	Decl.	Observer
Mar. 19.5779	$2^h\ 09^m\ 31^s.4$	−5° 47′ 25″	Morgan, Glasgow, Mo.

Comet *c* 1905 (Giacobini).—From "The Observatory" for March p. 118 we learn that this comet was photographed at Greenwich on January 8, before it passed perihelion. The photograph was taken in bright dawn, just before sunrise. On the original photograph four distinct tails can be made out, the longest being 1½′ in length. We have not learned of any observations being made since the perihelion passage.

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Mar. 1, 1906.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.	Name.	h	R. A. 1900. m	Decl. 1900. ° ′	Magn.
X Androm.	0	10.8	+46 27	12.5*d*	V Camelop.		49.4	+74 30	10.0 *i*
T "		17.2	+26 26	12.5	Z Aurigae		53.7	+53 18	11.0
T Cassiop.		17.2	+55 14	9.0 *i*	X "	6	4.4	+50 14	9.0
R Androm.		18.8	+38 1	9.3 *i*	V "		16.5	+47 45	10.4 *i*
Y Cephei		31.3	+79 48	11.5*d*	V Monoc.		17.7	− 2 9	9.5*d*
U Cassiop.		40.8	+47 43	11.7*d*	R "		33.7	+ 8 49	11.7
V Androm.		44.6	+35 6	9.8*d*	Nova Gem.		37.8	+30 3	<13.5
RR "		45.9	+33 50	<13	X Gemin.		40.7	+30 23	13.5
W Cassiop.		49.0	+58 1	12.0	W Monoc.		47.5	− 7 2	11
U Androm.	1	9.8	+40 11	14.5*d*	Y "		51.3	+11 22	14.5
S Piscium		12.4	+ 8 24	13.8*d*	X "		52.4	− 8 56	9.0*d*
U "		17.7	+12 21	<12	R Lyncis		53.0	+55 28	11.0*d*
R "		25.5	+ 2 22	12.5 *i*	RS Gemin.		55.2	+30 40	13.0
RU Androm		32.8	+38 10	12.5*d*	R "	7	1.3	+22 52	12.5*d*
Y "		33.7	+38 50	8.0 *i*	V Can. Min.		1.5	+ 9 1	14.5
X Cassiop.		49.8	+58 46	12.0*d*	R " "		3.0	+10 11	9.0 *i*
U Persei		52.9	+54 20	10.5 *i*	RR Monoc.		12.4	+ 1 17	<12
S Arietis		59.3	+12 3	14	V Gemin.		17.6	+13 7	14.0*d*
R "	2	10.4	+24 35	10.5*d*	S Can. Min.		27.3	+ 8 32	10.4*d*
W Androm.		11.2	+43 50	14	Z Puppis		28.3	−20 27	12
Z Cephei		13.0	+81 12.6	12.0 *i*	T Can. Min.		28.4	+11 58	9.5 *i*
o Ceti		14.3	− 3 26	5.3*d*	U " "		35.9	+ 8 37	10.0*d*
S Persei		15.7	+58 8	8.5 *i*	S Gemin.		37.0	+23 40	11.3*d*
R Ceti		20.9	− 0 38	11.0*d*	T "		43.3	+23 59	12.6 *i*
U "		28.9	−13 35	9.5 *i*	U "		49.2	+22 16	14.0
RR Cephei		29.4	+80 42	<14.5	U Puppis		56.1	−12 34	12.5 *i*
R Triang.		31.0	+33 50	7.8*d*	R Cancri	8	11.0	+12 2	10.4*d*
T Arietis		42.8	+17 6	9.2 *i*	V "		16.0	+17 36	12.2
W Persei		43.2	+56 34	10.4*d*	RT Hydrae		24.7	− 5 59	9.0
U Arietis	3	5.4	+14 25	9.4*d*	U Cancri		30.0	+19 14	14.0
X Ceti		14.3	− 1 26	13	X Urs. Maj.		33.9	+50 29	10.8 *i*
Y Persei		20.9	+43 50	9.0*d*	S Hydrae		48.4	+ 3 27	9.2*d*
R "		23.7	+35 20	9.5*d*	T "		50.8	− 8 46	12.6*d*
Nova Per. No. 2		24.4	+43 34	12.8*d*	T Cancri		51.0	+20 14	8.7*d*
S Fornacis		41.2	−24 42	8.0	S Pyxidis	9	0.7	−24 41	13.0
T Tauri	4	16.2	+19 18	11.5	W Cancri		4.0	+25 39	13.3*d*
W "		22.2	+15 49	11.0*d*	X Hydrae		30.7	−14 15	9.8 *i*
R "		22.8	+ 9 56	13.1*d*	Y Draco.		31.1	+78 18	12.5 *i*
S "		23.7	+ 9 44	10.2 *i*	R Leo. Min.		39.6	+34 58	9.6*d*
T Camelop.		30.4	+65 57	7.8 *i*	RR Hydrae		40.4	−23 34	11.5*d*
X "		32.6	+74 56	9.0 *i*	R Leonis		42.2	+11 54	7.7 *i*
V Tauri		46.2	+17 22	10.7 *i*	Y Hydrae		46.4	−22 33	7.3
R Orionis		53.6	+ 7 59	11.5*d*	V Leonis		54.5	+21 44	9.5 *i*
R Leporis		55.0	−14 57	9.3 *i*	R Urs. Maj.	10	37.6	+69 18	7.8 *i*
T "	5	0.6	−22 2	10.0*d*	V Hydrae		46.8	−20 43	8.6 *i*
V Orionis		0.8	+ 3 58	14 *d*	W Leonis		48.4	+14 15	13.3
R Aurigae		9.2	+53 28	12.5 *i*	S "	11	5.7	+ 6 0	9.9
W "		20.1	+36 49	14.5*d*	R Comae		59.1	+19 20	14.6*d*
S "		2.05	+34 4	11.0	RX Virginis		59.6	− 5 13	8.3
S Orionis		24.1	− 4 46	12.9 *i*	RW "	12	2.1	− 6 12	7.3
T "		30.9	− 5 32	10.5	T "		9.5	− 5 29	9.8
S Camelop.		30.2	+68 45	10.1*d*	R Corvi		14.4	−18 42	12.0*d*
RR Tauri		33.3	+26 19	12 *d*	T Can. Ven.		25.2	+32 3	9.0
U Aurigae		35.6	+31 59	13.5	Y Virginis		28.7	− 3 52	12.6*d*
Z Tauri		46.7	+15 46	13.5	T Urs. Maj.		31.8	+16 2	12.4*d*
RU "		47.3	+15 42	11.5	R Virginis		33.4	+ 7 32	7.2 *i*

Approximate Magnitudes of Variable Stars on Mar. 1, 1906.—
(Continued.)

Name.	h	R. A. 1900. m	Decl 1900. ° ′	Magn.	Name.	h	R.A. 1900. m	Decl. 1900. ° ′	Magn.
RS Urs Maj.	12	34.4	+59 3	11.0*d*	RU Herc.	16	6.0	+25 20	9.5*d*
S " "		39.6	+61 38	8.4 *i*	R Scorpii		11.7	−22 42	12.0
RU Virginis		42.2	+ 4 42	8.0 *i*	S "		11.7	−22 39	11.0 *i*
U "		46.0	+ 6 6	9.0*d*	W Coronae		11.8	+38 3	9.0*d*
RT "		57.6	+ 5 43	8.5 *i*	T Ophiuchi		28.0	−15 55	<12
V "	13	22.6	− 2 39	10.0*d*	S "		28.5	−16 57	9.0
R Hydrae		24.2	−22 46	6.9 *i*	R Draco.		32.4	+66 58	8.5 *i*
S Virginis		27.8	− 6 41	10.4*d*	RV Herc.		56.8	+31 22	12.0*d*
R Can. Ven.		44.6	+40 2	7.0 *i*	RT "	17	6.8	+27 11	<12
RR Virginis		59.6	− 8 43	12.3*d*	T "	18	5.3	+31 0	7.7 *i*
Z Bootis	14	1.7	−13 58	8.8*d*	W Draco.		5.4	+65 56	8.8*d*
S "		19.5	+54 16	8.2 *i*	X "		6.8	+66 8	<12
RS Virginis		22.3	+ 5 8	10.5*d*	R Cygni	19	34.1	+49 58	6.9 *i*
R Camelop.		25.1	+84 17	9.5*d*	RT "		40.8	+48 32	12.0*d*
V Bootis		25.7	+39 18	9.7*d*	TU "		43.3	+48 49	11.0
R "		32.8	+27 10	7.5 *i*	X "		46.7	+32 40	6.2*d*
V Librae		34.8	−17 4	9.5	Z "		58.6	+49 46	12.5*d*
U Bootis		49.7	+18 6	12.3*d*	S "	20	3.4	+57 42	<11.5
S Librae	15	15.6	−20 2	10.1*d*	RS "		9.8	+38 28	6.8 *i*
S Coronae		17.3	+31 44	7.7 *i*	R Delph.		10.1	+ 8 47	9.0*d*
RS Librae		18.5	−22 33	9.0 *i*	U Cygni		16.5	+47 35	8.9 *i*
X "		30.4	−20 50	<11	V "		38.1	+47 47	13.0
S Urs. Min.		33.4	+78 38	12.3	X Cephei	21	3.6	+82 40	<13
U Librae		36.2	−20 52	5.8	T "		8.2	+68 5	6.5 *i*
Z "		40.7	−20 49	9.0	S "		36.5	+78 10	11.7
R Coronae		44.4	+28 28	9.1 *i*	RU Cygni		37.3	+53 52	9.3
— "		45.3	+37 49	11.0	S Lacertae	22	24.6	+39 48	13.0*d*
V "		46.0	+39 52	<12	R "		38.8	+41 51	9.1 *i*
R Librae		47.9	−15 56	12.0	V Cassiop.	23	7.4	+59 8	12.1*d*
RR "		50.6	−18 1	<12	W Pegasi		14.8	+25 24	9.3d
Z Scorpii	16	0.1	−21 28	12.0	Z Cassiop.		39.7	+56 2	13.5*d*
RR Herc.		1.5	+50 46	8.7	RR "		50.6	+53 10	12.5*d*
U Serpentis		2.5	+10 12	<12	R "		53.3	+50 50	12.8
X Scorpii		2.7	−21 16	12.3	Y "		58.2	+55 7	11.0*d*
W "		5.9	−19 53	12.0					

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The above magnitudes have been compiled by Mr. Leon Campbell of the the Harvard College Observatory, from observations made at the Whiteside Vassar College and Harvard Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei.

	d	h
May	2	8
	4	20
	7	8
	9	20
	12	7
	14	19
	17	7
	19	19
	22	7
	24	19

U Cephei.

	d	h
May	27	6
	29	18

Z Persei

	d	h
May	2	5
	5	6
	8	8
	11	9
	14	11

Z Persei

	d	h
May	17	12
	20	13
	23	15
	26	16
	29	17

Algol.

	d	h
May	1	13
	4	10
	7	7

Algol

	d	h
May	10	4
	13	0
	15	21
	18	18
	21	15
	24	12
	27	9
	30	5

RT Persei

	d	h
May	1	11

RT Persei

	d	h
May	2	7
	3	4
	4	0
	4	20
	5	17
	6	13
	7	9
	8	6
	9	2
	9	23

Minima of Variable Stars of the Algol Type.—Continued.

RT Persei

May	d	h
	10	19
	11	15
	12	12
	13	8
	14	5
	15	1
	15	21
	16	18
	17	14
	18	10
	19	7
	20	3
	20	0
	21	20
	22	16
	23	13
	24	9
	25	6
	26	2
	26	22
	27	19
	28	15
	29	11
	30	8
	31	4

λ Tauri

May	d	h
	1	11
	5	0
	9	9
	13	8
	17	6
	21	5
	25	4
	29	3

R Canis Maj.

May	d	h
	1	9
	2	12
	3	15
	4	18
	5	22
	7	1
	8	4
	9	7
	10	11
	11	14
	12	17
	13	20
	15	0
	16	3
	17	6
	18	10
	19	13
	20	16
	21	19
	22	23
	24	2
	25	5
	26	8
	27	12
	28	15

Y Camelop.

May	d	h
	29	18
	30	21

Y Camelop.

	3	11
	6	18
	10	1
	13	9
	16	16
	19	23
	23	7
	26	14
	29	21

RR Puppis

May	5	17
	12	3
	18	14
	25	0
	31	10

V Puppis.

May	1	9
	2	20
	4	7
	5	18
	7	5
	8	15
	10	2
	11	13
	13	0
	14	11
	15	22
	17	9
	18	20
	20	7
	21	18
	23	5
	24	15
	26	2
	27	13
	29	0
	30	11
	31	22

S Cancri.

May	2	2
	11	13
	21	1
	30	13

S Antliæ.

Period $7^h\ 46^m.8$

May	1	13
	2	12
	3	12
	4	11
	5	10
	6	10
	7	9
	8	8
	9	8
	10	7
	11	6
	12	6

S Antliæ

May	d	h
	13	5
	14	4
	15	4
	16	3
	17	2
	18	2
	19	1
	20	0
	21	0
	21	23
	22	22
	23	22
	24	21
	25	21
	26	20
	27	19
	28	19
	29	18
	30	17
	31	17

S Velorum.

May	4	6
	10	4
	16	3
	22	1
	28	0

W Urs. Maj.

Period $4^h\ 0^m$

May 1-16 15^h

16-31 16

RR Velorum

May	1	2
	2	23
	4	19
	6	16
	8	12
	10	9
	12	5
	14	2
	15	22
	17	19
	19	15
	21	12
	23	8
	25	5
	27	1
	28	22
	30	18

Z Draconis.

May	2	23
	4	7
	5	16
	7	0
	8	10
	9	17
	11	2
	12	11
	13	19
	15	4

Z Draconis

May	d	h
	16	12
	17	21
	19	5
	20	14
	21	23
	23	7
	24	16
	26	0
	27	9
	28	18
	30	2
	31	11

δ Libræ

May	3	5
	5	13
	7	21
	10	4
	12	12
	14	20
	17	4
	19	11
	21	20
	24	4
	26	11
	28	19
	31	3

U Coronæ

May	3	20
	7	7
	10	18
	14	4
	17	15
	21	2
	24	13
	28	0
	30	11

R Aræ

May	4	5
	8	15
	12	2
	17	12
	21	22
	26	8
	30	18

U Ophiuchi.

May	1	7
	2	3
	3	0
	3	20
	4	16
	5	12
	6	8
	7	4
	8	0
	8	20
	9	17
	10	13
	11	9
	12	5

U Ophiuchi.

May	d	h
	13	1
	13	21
	14	17
	15	14
	16	10
	17	6
	18	2
	18	22
	19	18
	20	14
	21	10
	22	7
	23	3
	23	23
	24	19
	25	15
	26	11
	27	7
	28	3
	29	0
	29	20
	30	16
	31	12

Z Herculis.

May	1	13
	3	16
	5	13
	7	15
	9	12
	11	15
	13	12
	15	15
	17	12
	19	15
	21	12
	23	15
	25	12
	27	15
	29	12
	31	14

RS Sagittarii.

May	1	12
	3	22
	6	8
	8	18
	11	4
	13	14
	16	0
	18	10
	20	20
	23	6
	25	16
	28	1
	30	11

V Serpentis.

May	3	11
	6	22
	10	9
	13	20
	17	6

Minima of Variable Stars of the Algol Type.—Continued.

V Serpentis.

	d	h
May	20	17
	24	3
	27	14
	31	1

RX Herculis.

May	1	5
	2	3
	3	0
	3	21
	4	19
	5	16
	6	13
	7	11
	8	8
	9	5
	10	3
	11	0
	11	21
	12	19
	13	16
	14	13
	15	11
	16	8
	17	5
	18	3
	19	0
	19	21
	20	19
	21	16
	22	13
	23	11
	24	8
	25	5
	26	3

RX Herculis.

	d	h
May	27	0
	27	21
	28	19
	29	16
	30	13
	31	11

RR Draconis.

May	1	11
	4	7
	7	3
	9	22
	12	18
	15	14
	18	10
	21	6
	14	2
	26	22
	29	15

RV Lyræ

May	4	6
	7	21
	11	11
	15	2
	18	16
	22	6
	25	21
	29	11

U Sagittæ

May	2	7
	5	16
	9	1
	12	10
	15	19

U Sagittæ

	d	h
May	19	4
	22	13
	25	23
	26	8

SY Cygni.

May	4	12
	10	12
	16	12
	22	13
	28	13

WW Cygni.

May	2	1
	5	8
	8	16
	12	0
	15	7
	18	15
	21	23
	25	6
	28	14
	31	22

SW Cygni

May	3	4
	7	17
	12	7
	16	21
	21	11
	26	0
	30	14

VW Cygni.

May	4	5
	12	16
	21	2
	29	12

UW Cygni

	d	h
May	2	5
	5	16
	9	3
	12	14
	16	0
	19	11
	22	22
	26	10
	29	21

W Delphini

May	1	15
	6	10
	11	5
	16	1
	20	20
	25	15
	30	11

Y Cygni

May	1	6
	2	19
	4	6
	5	19
	7	6
	8	19
	10	6
	11	19
	13	6
	14	19
	16	6
	17	18
	19	6
	20	18

Y Cygni

	d	h
May	22	6
	23	18
	25	6
	26	18
	28	5
	29	18
	31	5

VV Cygni

May	1	15
	3	2
	4	14
	6	1
	7	12
	9	0
	10	11
	11	23
	13	10
	14	22
	16	9
	17	21
	19	8
	20	20
	22	7
	23	18
	25	6
	26	17
	28	5
	29	16
	31	4

UZ Cygni

May	9	4

Variable Stars of Short Period not of the Algol Type.

The times of maxima only are given; the times of minima may be obtained by subtracting the interval printed in parentheses under the name of the star.

Y Aurigæ

	d	h
	(−0	18)
May	3	2
	6	22
	10	19
	14	15
	18	12
	22	9
	26	5
	30	2

T Monocerotis

	(−7	22)
May	1	3
	28	3

W Geminorum

	d	h
	(−2	16)
May	7	16
	15	10
	23	4
	30	22

ζ Geminorum

	(−5	0)
May	11	3
	21	6
	31	10

V Carinæ

	(−2	4)
May	5	14
	12	7

V Carinæ

	d	h
May	18	23
	25	16

T Velorum

	(−1	9)
May	2	2
	6	18
	11	9
	16	0
	20	16
	25	7
	29	22

W Carinæ

	(−1	0)
May	2	20

W Carinæ

	d	h
May	7	5
	11	14
	15	23
	19	8
	23	17
	28	2

S Muscæ

	(−3	11)
May	6	5
	15	21
	25	12

T Crucis

	(−2	1)
May	6	11

T Crucis

	d	h
May	13	5
	19	22
	26	16

R Crucis

	(−1	9)
May	8	21
	14	16
	20	12
	26	8

S Crucis

	(−1	12)
May	8	1
	12	17
	17	10

Variable Stars of Short Period not of the Algol Type.—Continued.

S Crucis

	d	h
May	22	3
	26	19
	31	12

W Virginis

(−8 4)

May	5	21
	23	4

V Centauri

(−1 12)

May	1	23
	7	11
	12	23
	18	11
	23	23
	29	11

R Triang. Austr

(−1 10)

May	2	7
	5	16
	9	2
	12	11
	15	20
	19	6
	22	15
	25	23
	29	9

S Triang. Austr.

(−6 0)

May	6	16
	13	0
	19	7
	25	15
	31	23

S Normæ

(−4 9)

May	9	19

S Normæ

	d	h
May	19	23
	29	7

R V Scorpii

(−1 10)

May	4	18
	10	19
	16	21
	22	22
	29	0

X Sagittarii

(−2 21)

May	2	19
	9	20
	16	20
	23	20
	30	20

Y Ophiuchi

(−6 5)

May	9	5
	26	8

W Sagittarii

(−3 0)

May	1	8
	8	23
	16	13
	24	3
	31	18

Y Sagittarii

(−2 2)

May	3	3
	8	21
	14	16
	20	10
	26	5
	31	23

U Sagittarii

(−3 0)

	d	h
May	5	6
	12	0
	18	18
	25	12

β Lyræ

(−3 7)
(−3 2)

May	6	20
	13	2
	19	18
	26	0

κ Pavonis

(−4 9)

May	7	17
	16	19
	25	21

U Aquilæ

(−2 5)

May	3	15
	10	16
	17	16
	24	17
	31	17

U Vulpeculae

(−2 3)

May	5	11
	13	10
	21	10
	29	9

SU Cygni

(−1 8)

May	2	7
	6	4
	10	0
	13	20
	17	16

SU Cygni

	d	h
May	21	13
	25	9
	29	5

η Aquilae

(−2 9)

May	7	23
	15	3
	22	7
	29	11

S Sagittae

(−3 10)

May	2	2
	10	11
	18	21
	27	6

X Cygni

(−6 19)

May	3	23
	20	9

T Vulpeculae

(−1 10)

May	1	4
	5	15
	10	1
	14	11
	18	22
	23	8
	27	19

WZ Cygni Minimum

May	1	20
	3	0
	4	4
	5	9
	6	13
	7	17

WZ Cygni

	d	h
May	8	21
	10	1
	11	5
	12	9
	13	13
	14	17
	15	21
	17	1
	18	5
	19	9
	20	13
	21	17
	22	21
	24	1
	25	5
	26	10
	27	14
	28	18
	29	22
	31	2

TX Cygni

(−5 3)

May	6	11
	21	4

VY Cygni

(−2 2)

May	6	7
	14	4
	22	0
	29	21

δ Cephei

(−1 9)

May	5	5
	10	14
	15	23
	21	7
	26	16

Elements and Light Curve of VW Cygni.—In M. N. LXVI, p. 118, Mr. A. Stanley Williams gives new elements of this Algol-type variable, based upon observations in the years 1901-05.

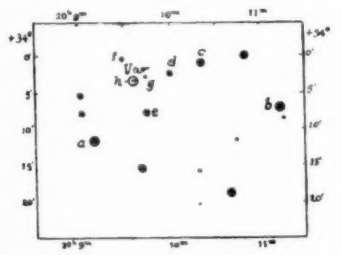
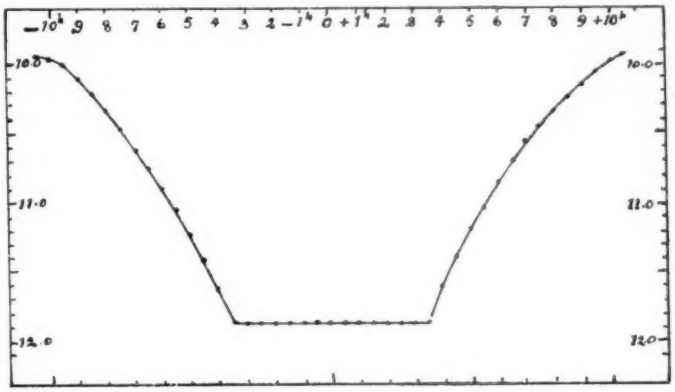


CHART OF VW CYGNI.

Minimum = 1901 Oct. 7, 17^h20^m G. M. T. + 8^d 10^h 20^m 04^s E.
= J. D. 2415655.722 + 8^d. 4306 E.

The normal brightness of the star is about 9.93 magnitude and at minimum it goes down to 11.87. The duration of the stationary period its 7^h 0^m and the whole duration of the eclipse phase 20^h 30^m. Because of the long duration of the



THE LIGHT CURVE OF VW CYGNI.

eclipse phase it would seem that one of the component stars is much larger and fainter than the other. There is no indication of a secondary minimum.

The following table gives the list of comparison stars used by Mr. Williams and their places are shown upon the accompanying chart:

Star	B. D. No.	B. D. Mag.	Light	Assumed Mag.
a	+34°.3936	8.5	80.0	8.20
b	+34°.3953	8.7	65.8	8.91
c	+34°.3946	9.2	52.3	9.58
d	+34°.3942	9.5	41.8	10.11
e	"	"	37.8	10.31
f	"	"	26.5	10.87
g	"	"	12.5	11.57
h	"	"	2.5	12.07

Elements and Light Curve of RV Lyræ.— In M. N. LXVI, p. 114, Mr. A. Stanley Williams gives new elements of this Algol-type variable bas-

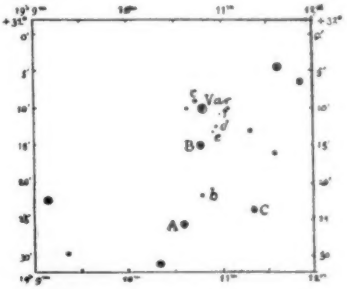


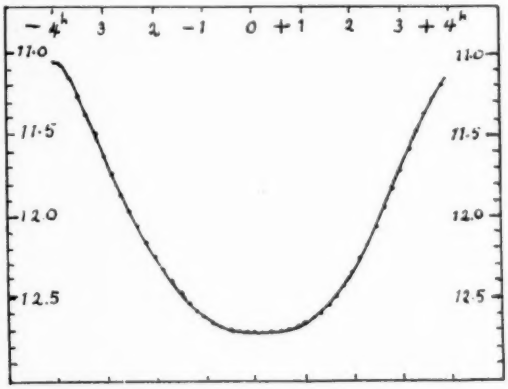
CHART OF RV LYRAE.

ed upon observations in 1893, 1901, 1902, 1903, 1904 and 1905.

Minimun = 1901 Oct. 7, 9^h 21.2^m G. M. T. + 3^d 14^h 22^m 34.7^s E.

= J. D. 2415665.3897 + $3.^d$599013 E.

The normal brightness of the star is about 11.06 magnitude and the minimum brightness 12.73. There is no stationary period at minimum. The star appears



LIGHT CURVE OF RV LYRAE.

to take a little longer in recovering its light than it did in losing it.

The accompanying chart shows the comparison stars used by Mr. Williams in his observations. Their adopted magnitudes are given in the following table:

Star	B. D. No.	B. D. Mag.	Light	Adopted Mag.
A	+32°.3376	9.2	0.0	8.61
B	+32°.3377	9.1	14.2	9.32
C	+32°.3380	9.4	26.7	9.94
b	"	"	41.2	10.67
c	"	"	63.6	11.79
d	"	"	63.6	11.79
e	"	"	72.6	12.24
f	"	"	78.2	12.54

GENERAL NOTES.

Occultation of Aldebaran, March 2, 1906.—Reports concerning the occultation of Adebaran which occurred on the 2nd day of last month have been, so far, uniformly disappointing. Cloudy weather is reported as the cause.

The Occultation of Aldebaran on the evening of March 2nd was observed at Cedar Rapids under rather remarkable circumstances. The day had been rainy and in the evening was enshrouded in fog. Scores of disappointed students, who had planned to watch the occultation, gave up hope of seeing it at all. But shortly before nine o'clock the fog lifted, rifts appeared in the clouds near the moon, and a clear space opened up just in time for us to see the star dis-

appear on the moon's invisible edge. A few moments later the clouds gathered again and a snow storm followed. It seemed as if the temporary clearing were a special favor of Providence.

As nearly as could be judged from an ordinary watch, the immersion occurred at 9h. 18m., c. s. t. The emersion was, of course, not observed.

LEROY D. WELD.

Coe College.
Cedar Rapids, Iowa.

Dr. E. D. Roe, Jr.,—John Raymond, French Professor of Mathematics in Syracuse University, has purchased of Mr. T. A. Lawes, Mechanical Engineer of the New York, Chicago and St. Louis R. R., the 6½-inch telescope made by Alvan Clark & Sons for Mr. Lawes in 1897. The telescope is an equatorial about 9 ft. in length of the Lowell type and is of fine design, with powerful driving clock of the Young pattern, and separate clock to drive hour circle, has slow motions governed at eye end and is well supplied with accessories. Through the excellent care given it by Mr. Lawes and the refinishing which it will receive at the hands of the Alvan Clark & Sons Corporation, it will be delivered practically as good as new. Prof. Roe will have it mounted at his residence in Syracuse.

The Great Montana Meteor.—About the middle of January last, reports in the paper, gave notice of the fall of a splendid meteor, somewhere in the north central part of Montana. The flashing light and the loud report of its detonations were heard and seen in a radius of 50 miles around Chinook which is located on the Great Northern Railway, on Milk River, near the middle northern part of the State.

Wishing to know more about this meteor, we wrote to the Hon. J. W. Stone of Chinook for further information, who was kind enough to secure a number of interesting personal letters from persons who had either witnessed the meteor in its flight, or, had some information about it thought to be of scientific value.

Fred H. Scott of Clearcreek, heard its report, as a loud hissing sound though a typewriter was busy near him at the time.

W. F. Purdy of Lloyd about twenty miles south of Chinook saw the meteor in flight, as he thinks, about three seconds; thirty seconds later he heard its report. "It looked like a great ball of fire." While in sight it burst into two equal parts forming two streaks at a small angle with one another one-half of its visible flight. He had no idea how far it was away.

F. B. Rodgers, postmaster, of Maddux was also fortunate enough to witness this remarkable meteoric display. He says the meteor moved in a northwesterly direction, left behind it a train that looked like "a streak of sparks," and suddenly there came a flash like lightning and it then disappeared, and the report of the explosion followed in 30 seconds. He expected to hear the explosion soon for he had witnessed two other such meteoric displays and heard the accompanying detonations of each.

This explosion was like a heavy blast followed by a roaring sound that died away in the distance.

It is noteworthy that some of the observers speak of the meteor as appearing directly over "Big Baldy" Mountain which can be seen in the far distance from Chinook. All speak of the loud hissing noise that accompanied the visible flight and some seconds later.

New Cipher Code, Gerrish System.—A circular sent out by Professor E. C. Pickering, Director of Harvard College Observatory under date of March 5, 1906, announces that on and after March 15, 1906, cipher telegrams sent out from the Harvard Observatory will be in a new code devised by Mr. Willard P. Gerrish, of that Observatory. The character and simplicity of the code may be best illustrated by the copy of the "Form A", given on the opposite page, which may be used for transmitting the position of a comet or asteroid. The code consists essentially of eleven two-letter syllables representing the digits 1 to 9, 0 and a space not utilized, together with blank forms by which the numbers usually employed in indicating the position of planet or comet may be arranged in their natural order and at the same time in five groups of five figures each. Thus the Greenwich mean time of the observation to the fourth decimal of a day, the right ascension to the tenth of a second of time, the declination to the second of arc and the brightness of the object on a scale of five, together with a check number which is the sum of the other five, may all be communicated by six five-syllable words. Had the discovery of the new comet by Kopff been announced in this code, the message would have read

Kopff comet uxamuxfiux fikuotomvy babafikuku amvydeuxba gouxvyvyvy kufikugoam.

Our reading this message would immediately find the numbers.

06030,3596 —, 11355,6 — 201,40 — — —, 53546,

the dashes signifying spaces not utilized. Counting the dashes as zeros and adding the first five numbers the sum is found to be 153546, which satisfies the check. Regrouping the figures according to the "form" we have

'06 March 3.576 R. A. $11^h\ 35^m\ 56^s$ Decl. $+1°\ 40'$.

"Form B", which is too large to be given on one of our pages, may be used for transmitting in eighteen words the elements of a comet's orbit and an ephemeris giving the right ascension and declination on four dates and the brightness on two dates.

"From C" gives several forms for miscellaneous telegrams.

No code book is necessary. A small phamphlet is sent out with the blank forms explaining their use and especially the methods of detecting errors. The blank forms themselves, however, contain all that is really necessary for their successful use.

The advantages of the system as stated by Mr. Gerrish are:—

(a) The avoidance of reductions.

(b) The preservation of the natural order of the quantities transmitted.

(c) Simplicity of plan, avoiding complicated rules which are not easily understood or remembered.

(d) The use of printed forms by which the division of numbers and assignment of proper denominations are affected graphically.

(e) The translation of numbers to and from code without the use of a code book.

(f) Rapidity of translation.

(g) The possibility of detecting and rectifying error by inspection.

On the Rights of Discoverers and Others.—Concerning our short note in *Popular Astronomy* for March and Mr. Crommelin's reply to its "final paragraph" in the same number, three remarks seem to exhaust all that we shall care to add to the subject.

I. We have not proposed, nor do we hold, the theory" that the discoverer of a

A

HARVARD COLLEGE OBSERVATORY

TELEGRAM FOR POSITION

GERRISH SYSTEM

G. M. T.				R. A.				Dec.				Brightness 1–5	Check
Year	Month	Day	Decimal	h.	m.	s.	Dec.	±	°	′	″		
1		2		3		4		5					6

Directions:—Write one figure in each space, using ciphers (syllable "ux") where no significant figures are called for. If it is desired to express quantities with less accuracy than is provided for by the form, use the syllable "vy" for each space not utilized in consequence.

Decimal of day to be reckoned from Mean Noon.

Use the figure 2 for a plus (+) sign, and the figure 1 for a minus (—) sign.

Brightness on scale of five: —1, Conspicuous; 2, Naked eye; 3; Opera glass; 4, Small Telescope; 5, Large Telescope.

To obtain "check" add together the first five numbers, discarding the left hand figure if the sum is a number of six figures.

Syllabic code.

1	2	3	4	5	6	7	8	9	0	not utilized.
ba	de	fi	go	ku	am	en	ip	ot	ux	vy

Address:—Telegrams should be addressed to "Harvard College Observatory, Cambridge, Mass."; cablegrams to "Observatory, Boston."

new body is its sole proprietor, and the only person who has the right to draw deductions from observations of it that have been publicly given to the astronomical world." Our statement that "Such an incident raises the question of the rights of a discoverer to the fruits of his labor" hold no such meaning as that ascribed by Mr. Crommelin.

II. If from published observations an astronomer, *on his own initiative*, discovers that a satellite orbit is retrograde, and publishes the fact immediately, we have a commendable condition.

But when one astronomer publishes, most kindly, that "There is a remarkable feature about the orbit (of Phoebe) which, however, I must not mention here, as the discoverer wishes to make the first announcement himself in a number of *The Harvard Annals* just passed for press," and when another astronomer confesses * "that it was this that led me to undertake the work of deducing the orbit," including the "remarkable feature" referred to, and that he "felt perfectly justified in publishing it" immediately, we have a very different condition: a condition, in our opinion, in complete harmony with the contents of our "final paragraph."

We think that the "astronomical value" of Mr. Crommelin's work on the orbit would have been equally great—or greater—if he had delayed its publication until after the appearance of "*The Harvard Annals* just passed for press."

III. We studiously kept out of this controversy for a full year, and hoped that the subject was closed: any controversy of this sort is most unfortunate. But Mr. Crommelin's reiteration of his criticisms, in strong language, in a formal presidential address, before an established society, forced us to break silence.

W. W. Campbell,
C. D. Perrine.

Gold Medal of the R. A. S. Awarded to Professor W. W. Campbell.—The following extract from the minutes of the Annual General Meeting of the Royal Astronomical Society as given in the March *Observatory* will be of interest to our readers, as showing in what esteem one of the foremost American astronomers is held in England. We congratulate Professor Campbell on this recognition of his splendid work.

"*The President* then announced that Mr. Whitelaw Reid, the American Ambassador, who would receive the Medal on behalf of Professor Campbell, was already within the building, and suggested that, contrary to usual custom, the awarding of the Medal should take place before the presentation of the Report. This was acceded to, and the American Ambassador, escorted by Sir William Huggins, entered the room. *The President* announced that the Gold Medal of the Society had been awarded to Professor William Wallace Campbell, Director of the Lick Observatory, for his spectroscopic researches, which have greatly increased our knowledge of stellar motions. He then gave a comprehensive account of Professor Campbell's work, dealing successively with the early history of the spectroscopic measurement of stellar velocities in the line of sight, with Professor Campbell's design of the Mills spectrograph at the Lick Observatory and the important work done with that instrument, including his discovery of many spectroscopic binaries, and his preliminary determination of the Sun's motion in space from data founded on his spectroscopic observations. Professor

* Crommelin, Popular Astronomy, March, 1906, p. 148.

Campbell's researches in other branches of astronomical spectroscopy were also referred to. In conclusion he said:—

'It is a matter of regret to us all that it has not been possible for Professor Campbell to be with us this afternoon to receive in person the Medal which has been awarded to him. But in view of the fact that it is only a few months since he visited Europe, and of the important work which he has in hand at Mount Hamilton, Professor Campbell's absence, although as I have said, a matter for regret, is not one for surprise. Moreover, we are not without a compensation. It has on many occasions been our pleasure to heartily welcome in this room Mr. Choate, for so many years the American Ambassador in this country, and now Professor Campbell's absence has afforded us the opportunity of extending an equally cordial welcome to Mr. Whitelaw Reid, who has succeeded Mr. Choate in his most important office, and who will, I am sure, also succeed him in the esteem and regard of the British nation.

There is a special fitness in Mr. Reid's presence here to-day, as I have learned that—by a peculiarly happy coincidence—he is the son-in-law of Mr. D. O. Mills, through whose munificence it was rendered possible not only to construct the Mills Spectrograph but also to organize and carry out those observing expeditions to Chile which have proved such an extremely valuable aid to Professor Campbell's scheme of research.

Mr. Reid, in handing you this Medal which you have kindly undertaken to transmit to Professor Campbell, I will ask you to assure him of the very deep interest which we in England take in the important work which he is so successfully prosecuting, and to express to him our high appreciation of the influence which his researches have exerted—and still are exerting—on the development of astronomical knowledge'

Mr. Whitelaw Reid. It is a great pleasure to me to be the medium of transmission of this very high token of your appreciation of the labors of my distinguished fellow-countryman. It gives me great pleasure to take part in the ceremony to-day, and to hear the learned address of the President expressing such generous appreciation of Professor Campbell's work. Professor Campbell will value this decoration as highly as any statesman would value a decoration awarded to him by his government for distinguished political services. On his behalf, and in the name of the United States, I beg to express my profound thanks, and I think I may add the thanks of the staff of the Lick Observatory, for this honor conferred on its Director. My country is always proud of any advance in art or science made by her sons—prouder far of that than of triumphs in commerce or war. The American people, therefore, will be highly gratified at this mark of your Society's approval, especially as it comes from a country with which we are closely related, and to the opinion of which we are wont to attach great importance."

Corrections to the List of Variable Stars of Short Period.—We are very grateful to Mr. Seares for sending in the corrections which he has found to our revised list of Variable Stars of Short Period in the February number of Popular Astronomy p. 74 (see this number p. 238). It should be said in accounting for the omissions that the list was prepared some two months before it was printed and that some of the data for the coreections have come to hand since that time. We shall be glad of any further corrections which may be made. S. Antliæ, we notice, is still retained on the list of Algol-type stars in the *Companison to the Observatory* for 1906.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the first of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription are sent directly after the last number of this publication for which payment has been made. It is especially requested that subscribers will send renewal, or order for renewal, promptly as this publication will not be continued beyond the time for which it has been ordered.

Astronomical News.—It is very much desired on the part of the management, that brief news paragraphs of astronomical work in all the leading observatories of the United States be furnished to this publication, as regularly and as often as possible.

The work of amateur astronomers, and the mention of "personals" concerning prominent astronomers will be welcome at any time.

The building and equipping of new observatories, the manufacture, sale or purchase of new astronomical instruments, with special reference to improvements and new designs, and the results of new methods of work in popular language, will be deemed very important matter and will receive prompt attention. It is greatly desired that all persons interested bear us in mind and promptly respond to these requests.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should order them when the manuscript is sent to the publisher. They cannot be furnished later without incurring much greater expense.

Subscription Price Changed. Beginning with the Jannary number the price of Popular Astronomy a volume, of ten numbers each, to subscribers living in the United States, its territory, Canada and Mexico was changed to $3.50; the price to all others is $4.00; in each case payable strictly in advance.

Back volumes or single numbers are still on sale at the old prices, $2.50 and 30 cents, respectively.

WM. W. PAYNE,
Northfield, Minn., U. S A.